Sericulture training manual

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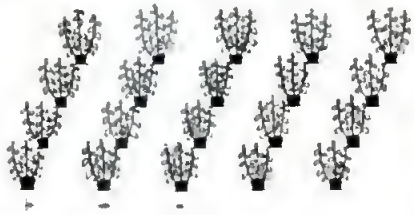
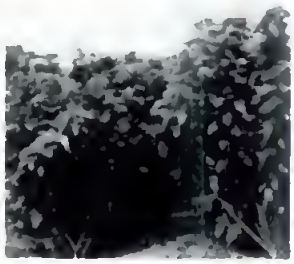
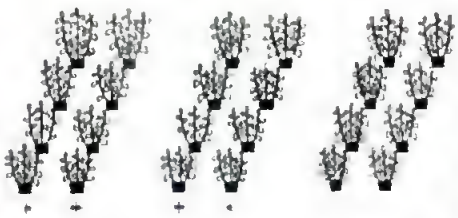
(a) Single rows in high plant density





(b) Rows with paired plants



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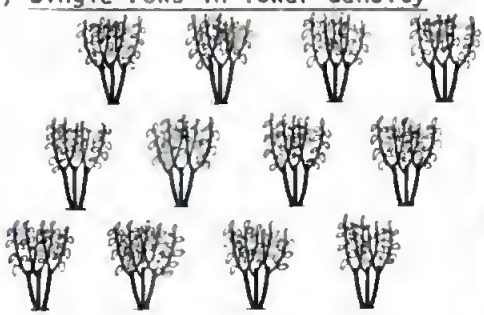

FOOD
AND
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Sericulture training manual

FAO
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SERVICES
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80

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ORGANIZATION
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Rome, 1990

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FOREWORD

Sericulture, and the silk industry in general, covers a wide range of techniques, ranging from agricultural mulberry tree cultivation and biological silkworm rearing to industrial silk production and processing. Both effective dissemination and efficient extension of technology for cocoon and silk production are essential to meet the increasing global demand for quality cocoons and fine silk, as ever more developing countries become interested in both cocoon and silk production. Regional development of the correct, systematic technology is necessary for success in both mulberry cultivation and silkworm farming in which the most important factor is the natural environment as determined by meteorological and soil conditions.

Keeping the above in mind, the authors have tabulated fundamental data and illustrated the basic principles of sericulture so that they can be readily understood even by farmers who have no previous experience or knowledge of sericulture. This manual also can be utilized as a reference and guide material for teachers, extension workers and administrative staff for development planning. The techniques in this book are mainly concerned with bivoltine silkworm rearing in the temperate zone. Many tropical countries are trying to adopt bivoltine rearing which produces more cocoons and better quality silk than multivoltine rearing. Utilization of this book as a guide for multivoltine rearing in the tropical zone should, therefore, be carefully modified before application. It is recommended that methods and technqiues in this book should be applied only after local testing, especially for mulberry cultivation and pest control. However, only minor modifications will be necessary for egg production and silkworm rearing.

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Chapter 1: MULBERRY CULTIVATION

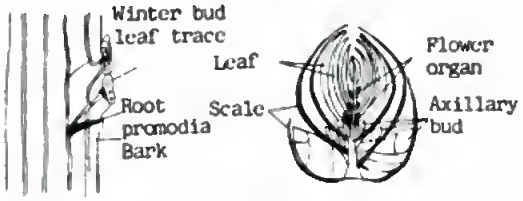
1.1 INTRODUCTION

The Bombix mori silkworm is monophagous, feeding only on the leaves of the mulberry tree (Morus). Probably originating in the foothills of the Himalayas, mulberry trees are now found within a very wide geographic distribution, extending from temperate to tropical zones, and from sea level to altitudes exceeding 4 000 metres (see Appendix I (a)). The Morus genus has more than twenty species and at least one hundred varieties. The object of good mulberry cultivation is the production of large quantities of good quality leaves of high nutritive value. Accordingly, the first chapter of this manual on sericulture is concerned with the cultivation of the mulberry tree in order to ensure such production.

1.1.1 Anatomy of Mulberry Tree: Before looking at the development and use of mulberry trees, several aspects of their physical structure and function need to be examined.

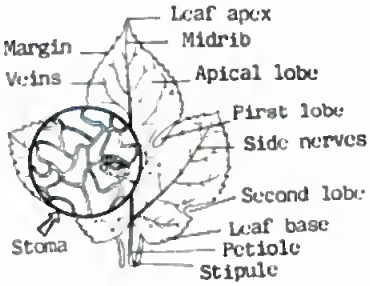
(a) Winter bud: The following diagrams show the emergence of a winter bud from a twig (A); and a longitudinal section of a winter bud (B).

(A)

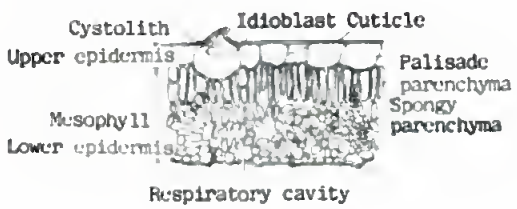


(B)

(b) Leaf: Leaves assimilate materials necessary for the growth of a tree: A shows the various parts of a leaf and B gives a cross-section.

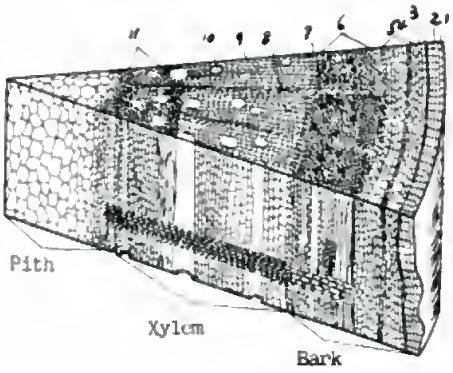


(A)

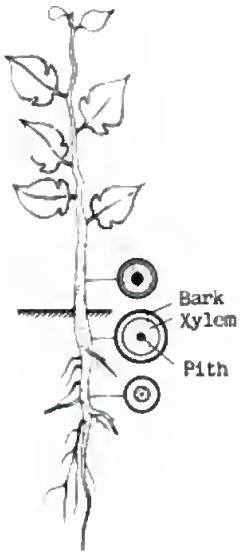


(B)

(c) Stem:

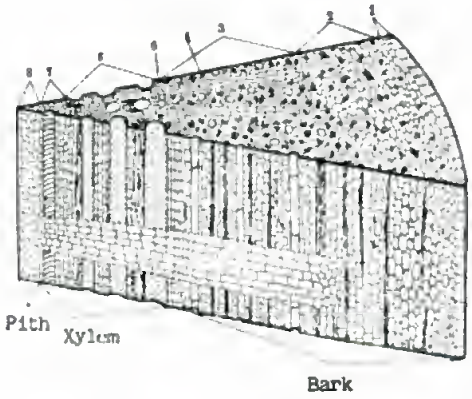


1. Epidermis
2. Cork layer
3. Phellogen
4. Phelloderm
5. Primary cortex
6. Phloem
7. Cambium
8. Medullary ray
9. Xylem parenchma
10. Vessel
11. Primary xylem



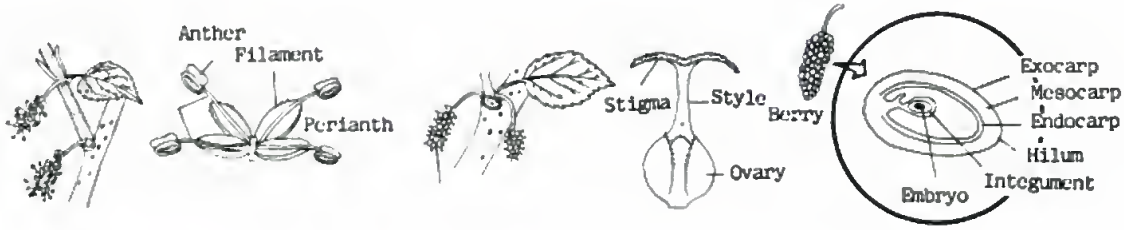
Young sapling

(d) Root:



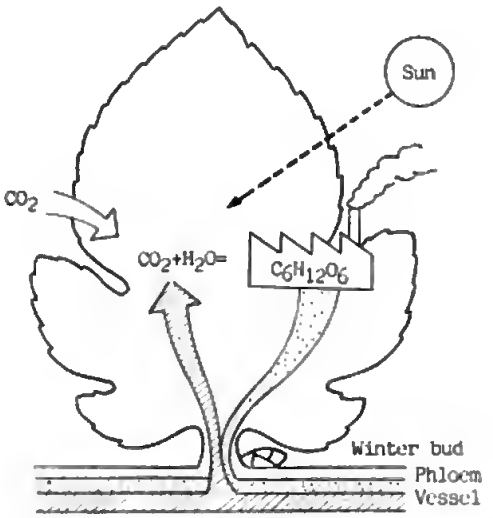
1. Periderm
2. Primary cortex
3. Phloem
4. Medullary ray
5. Cambium
6. Secondary xylem
7. Primary xylem
8. Pith

(e) Flower and seed:



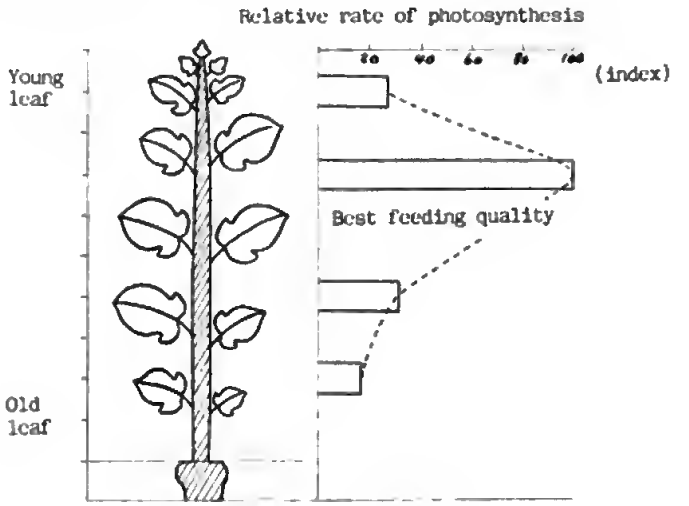
1.1.2 Leaf Production and Utilization of Materials: Leaves act as a factory, manufacturing carbohydrates from carbon dioxide, water and sunlight. They also synthesize other materials which are required for the tree. The average daily rate of growth of mulberry shoots during spring and summer is approximately 1cm and 3cm respectively.

(a) Production

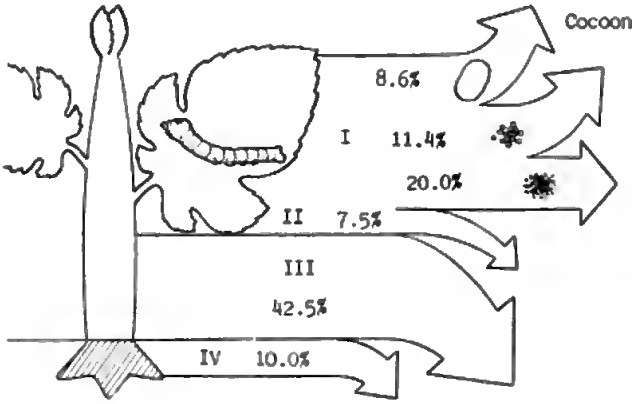


Photosynthesis

In sericulture both the quality and the quantity of leaf production are important. Leaf age is an important factor for photosynthetic activity and, therefore, for the feeding quality of the leaf. The following diagram shows the relationship between leaf age and photosynthetic activity.



(b) Utilization of photosynthetic products: The photosynthetic products of the mulberry plant are used to sustain sericulture and are needed to maintain the tree in a healthy condition in its growth and respiration. The following diagram shows the relative proportions of photosynthetic product utilized by the silkworm and the various parts of the plant.

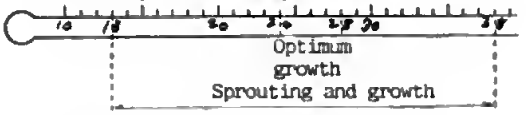


I. Through the silkworm
II. For plant growth
III. For stem and branch
IV. For the root system

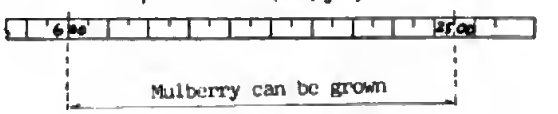
1.1.3 Climate and Soil Conditions: Given the wide geographical distribution of mulberry cultivation, physical conditions such as climate and soil quality necessarily vary considerably, giving rise to the development of specific regional varieties. Cultural practices such as planting densities, training patterns, pruning and harvesting methods, soil and water management vary according to those factors. Optimal physical conditions are set out below.

(a) Climatic conditions

* Atmospheric temperature (°C)



* Precipitation (mm/yr)

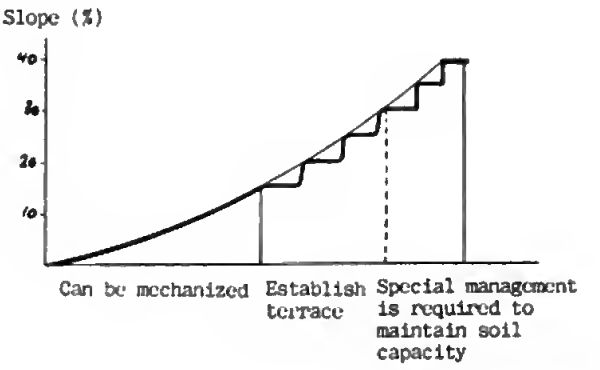


* Photoperiod: 9-13 hrs/day

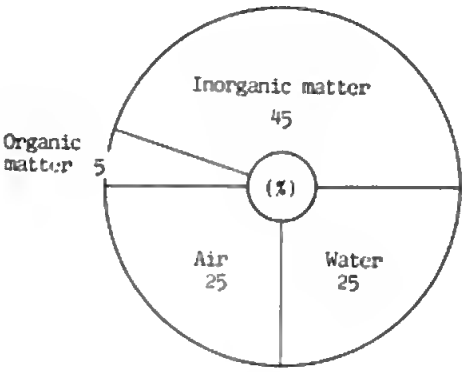
* Atmospheric humidity: RH 65-80%

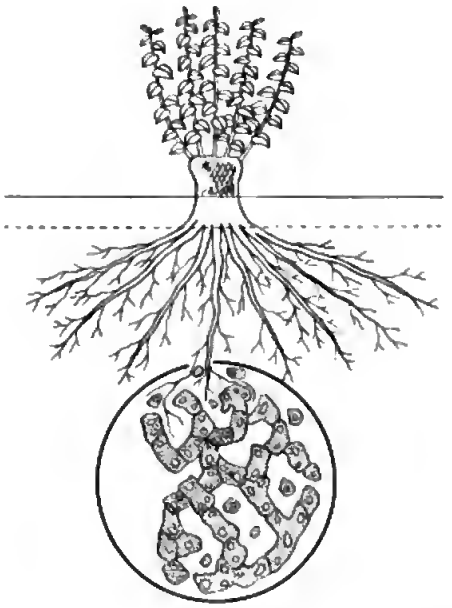
* Elevation: up to 700m, though depending on latitude

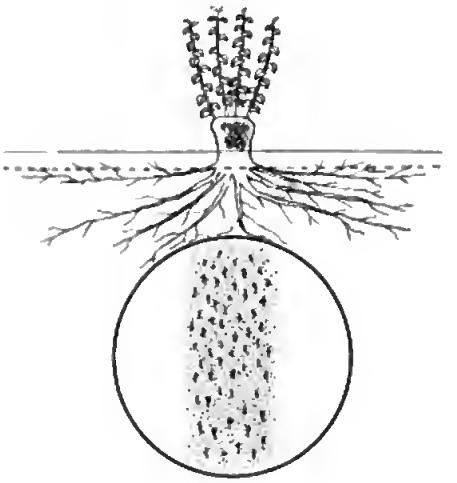
(b) Morphological conditions: The ideal terrain for mulberry cultivation will have a gradient below 15% as mechanization is practicable and soil erosion minimal. Above 15% special treatment will be necessary (see 1.3.6.).



(c) Soil conditions: Physical and chemical characteristics of a soil, its water retention ability, pH reaction and lime and humus content have a marked effect on mulberry longevity, strength and leaf yield. The pie-chart shows the ideal soil composition for mulberry cultivation. Because of its perennial nature and, therefore, of its deep root system good soil conditions are vital for the continuing productivity of the tree as the following diagrams indicate.



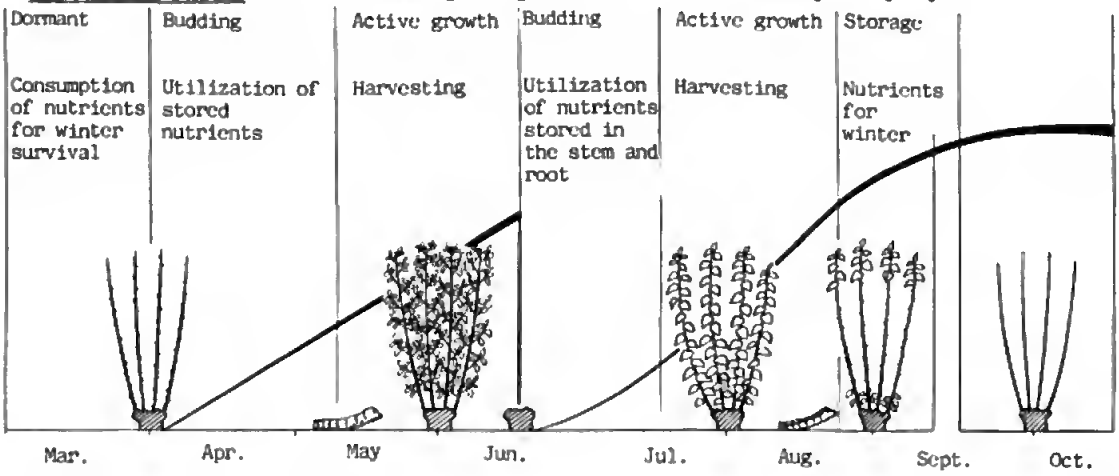




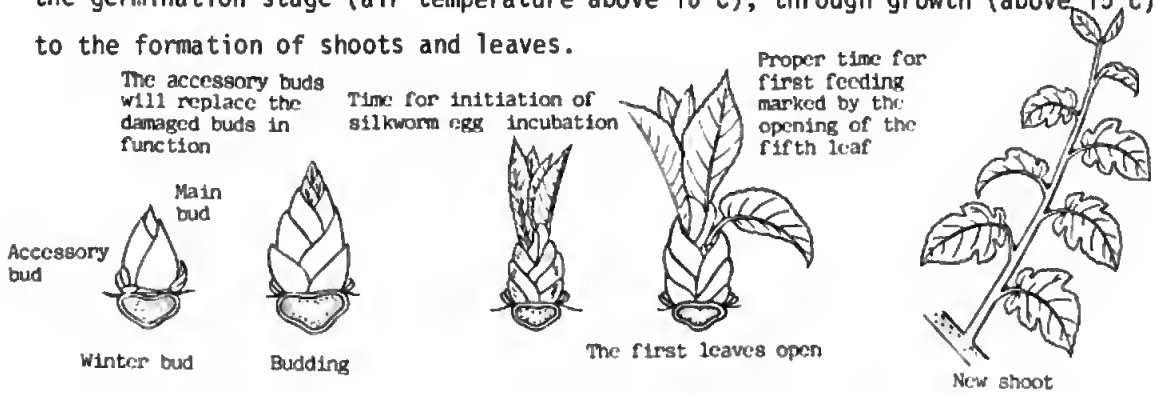
Deep	Surface soil	Shallow
More than 60cm	Available soil depth	Less than 30cm
Loamy or sandy-loam	Soil texture	Clay
Less than 25mm	Hardness (Yamanaka hardness tester)	More than 25mm
Good	Drainage	Bad
Lower than 1m	Water level	Higher than 1m

1.1.4 Mulberry Development under Cultivation: The natural life cycle of the mulberry has been modified under cultivation, depending always on the agroclimatic and cultural conditions. With the aim of harvesting the greatest quantity of good quality leaves the natural cycle has been modified in temperate zones to provide two harvests a year, whereas in tropical zones as many as five are possible.

(a) Temperate zones: The following diagram charts a normal yearly cycle.



* Budding process: The diagram below shows the development of a winter bud from the germination stage (air temperature above 10°C), through growth (above 15°C) to the formation of shoots and leaves.



(b) Tropical zones: Because of agroclimatic conditions in tropical zones much greater flexibility is possible in moriculture enabling multi-cropping to be practised (see 1.4.6). The diagram below shows a possible year-cycle in tropical zones. Because repeated harvests will deprive the plant of stored nutrients necessary for budding and growth, attention is needed to ensure plant health.

Budding	Growth (harvesting)	Budding	Growth (harvesting)	Budding	Growth (harvesting)	Budding	Growth (harvesting)

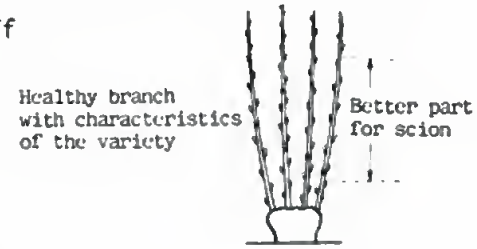
1.2 PROPAGATION

The aim of propagation is to produce as many individual plants as possible which reproduce the characteristics of a chosen parental stock. Plants may be propagated through seeds or by vegetative methods, however, except for the production of stocks for grafting purposes (see 1.2.1) seeding is not generally recommended as there is little control over the quality of the tree produced. The most commonly used methods are grafting, softwood cutting and layering.

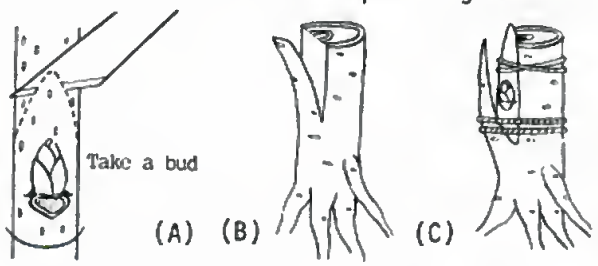
1.2.1 Grafting: To maintain the characteristics of a selected variety, grafting is a favoured method in temperate zones where the agroclimate is not suited to the easier cutting method. A higher degree of skill and labour demand is needed.

(a) Stock: The root base on which a graft is joined is grown from seed (2-3% volume of berry); seeds are planted in prepared beds (401 seeds/ha = 700 000 to 800 000 seedlings/ha); seedlings cut off above the root provide stocks for grafting.

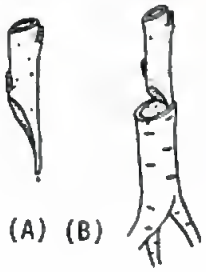
(b) Scion: A section is cut from the healthy branch of a tree of the desired variety.

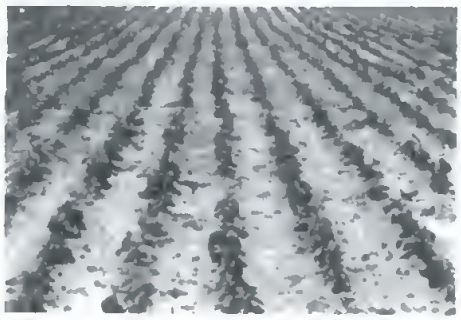


(c) One-bud grafting: A scion containing one bud, including a small portion of woody tissue is cut from the desired branch (A); an incision is made in the root stock (B); the scion is then inserted and bound with twine or tape for good contact (C).



(d) Sack grafting: A scion with two buds (A) is inserted into a pocket created between the bark and the wood (B).

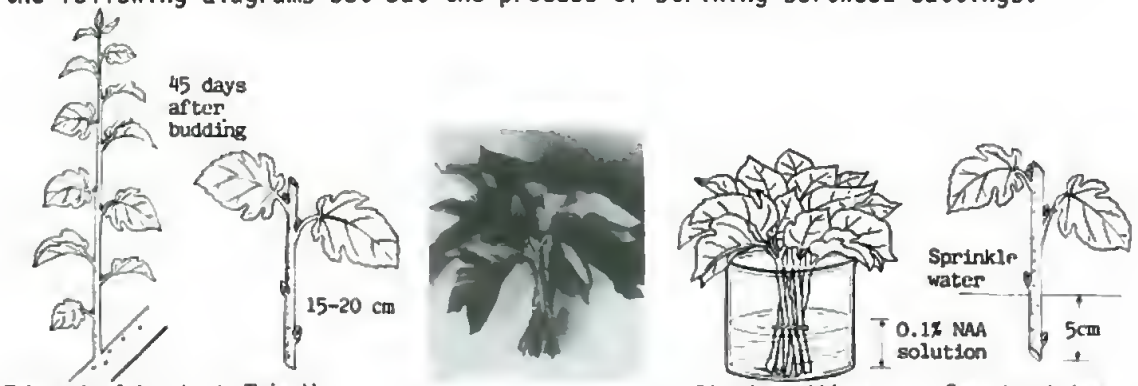




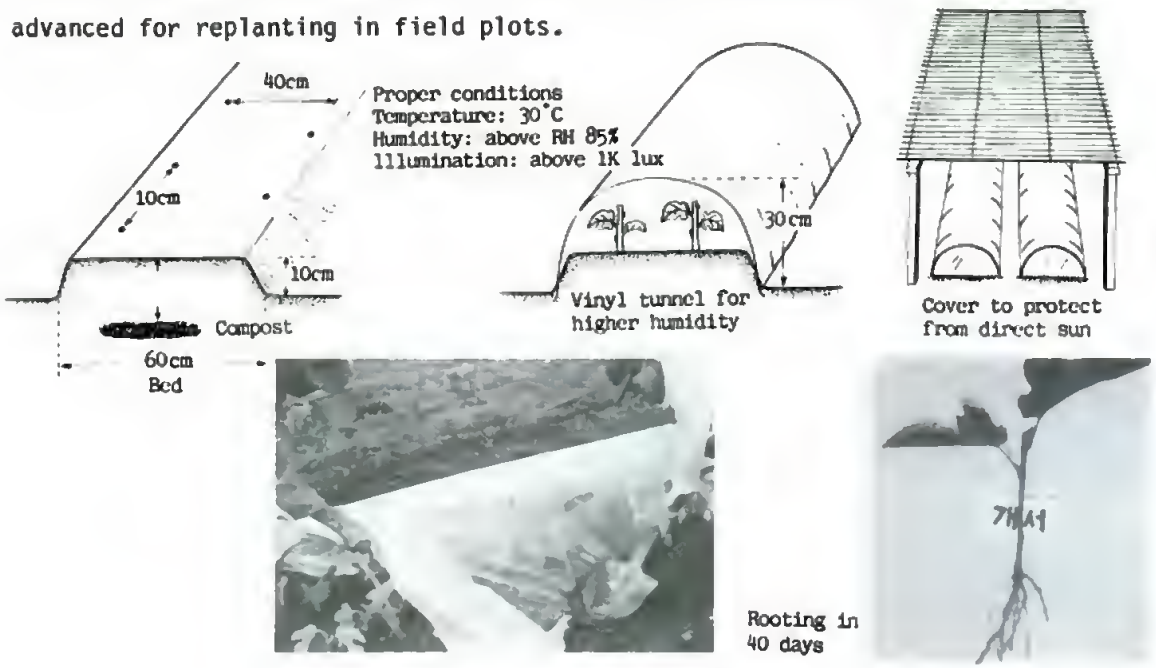
The grafted plants are bundled and preserved at 25-30°C for two weeks to form calluses before being planted out.

1.2.2 Softwood Cutting: Branch cuttings take relatively good roots if inserted in the soil. In humid sub-tropical and tropical zones cuttings may be planted directly into field plots; in temperate or less humid sub-tropical regions cuttings must be treated to promote rooting and then be planted in specially prepared beds before being planted out in field plots.

(a) Striking: Applicable to temperate zones and less humid sub-tropical zones, the following diagrams set out the process of striking softwood cuttings.



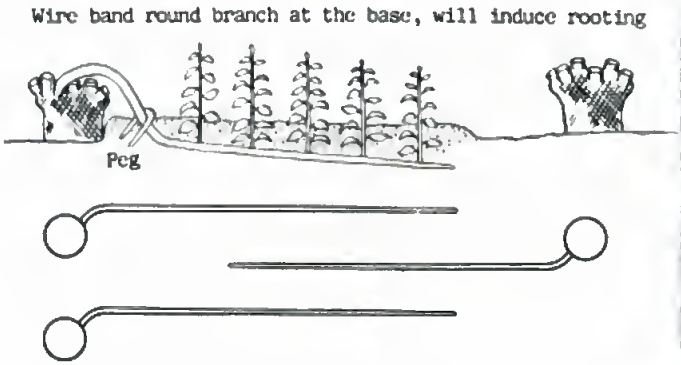
(b) Nursery stage: In temperate zones a humid microclimate must be artificially created and the soil specially prepared to ensure the most favourable conditions for quick growth. After 40 days the rooting system should be sufficiently advanced for replanting in field plots.



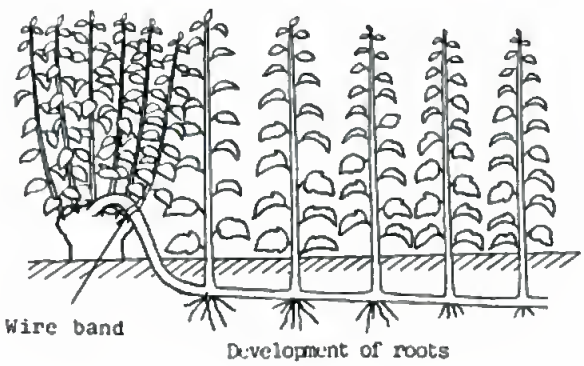
1.2.3 Layering: One of the most effective and secure methods of propagation, layering requires an established mulberry field, is not appropriate for mass production and requires considerable labour. On the other hand, in temperate zones this system enables new plants to be propagated at minimal expense.

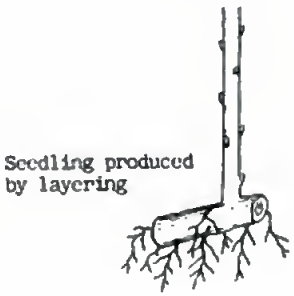
(a) Preparation of bed: Propagation will be most effective if the ground into which the branch is to be placed is specially prepared with compost and the level near the base of the tree is raised as shown below.

(b) Layering method: One or two branches are buried to the depth of about 20cm leaving 5-6 shoots exposed; a peg is used to secure the branches. Care must be taken when weeding to ensure that the new rooting system is not disturbed.



(c) Harvesting saplings: The tops of the shoots may be harvested and when the individual root systems are developed (days) the lateral should be cut between the new shoots providing saplings ready to be planted in field plots.

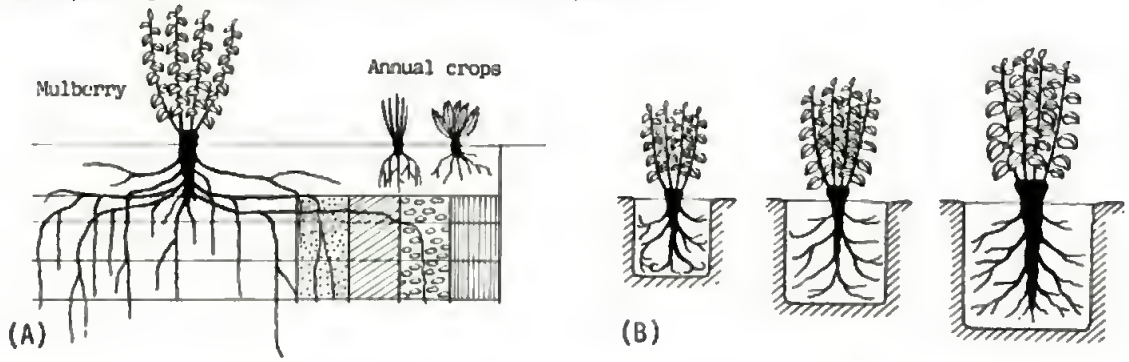




1.3 PLANTING AND CULTIVATION

1.3.1 Planting: Planting practice depends very much on climatic and soil conditions in a specific area, however careful attention must always be given to ensure that beds are properly prepared.

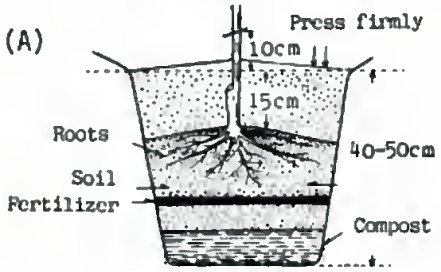
(a) Mulberry root system: Being a perennial the mulberry has an extensive root system (A) and it must always be remembered in the preparation stage that the initial trench for the saplings will determine the range of root development and, consequently, the extent of branch development (B).

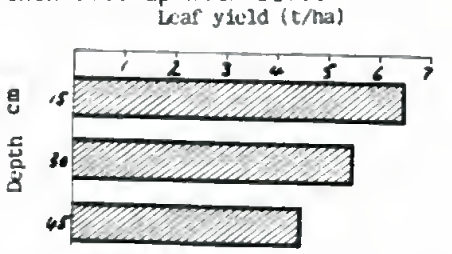


(b) Preparing trenches: The best time to improve the physical condition of the soil is when the land is being prepared for planting. Taking into account the extent of the mulberry root development, large trenches should be dug, all diseased and rotten roots removed and a layer of organic matter placed at the bottom of the trench. This practice will ensure both full and healthy development of the tree. Depending on the physical condition of the land and such factors as labour resources, degree of mechanization and so on, the trenches may be prepared by hand tools (A) or by tractor-drawn plough (B) (in difficult terrain heavy-duty plant may need to be used (C)).

(A) (B) (C)

(c) Planting method: Select uniform-sized saplings for uniform growth after planting. Place the sapling in specially prepared trench (A) taking care to avoid direct contact between roots and fertilizer, then fill up with soil.

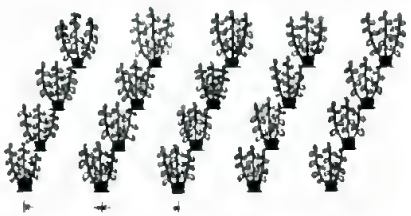




15cm is ideal for better yield

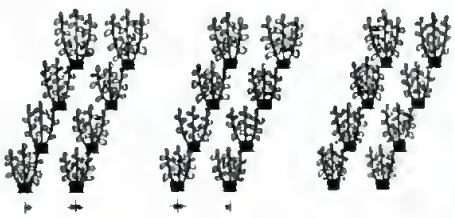
1.3.2 Establishment of Mulberry Field: The field arrangement of the plants will greatly affect both yield and leaf quality. Factors such as agroclimate, soil fertility, cultivation practice will dictate which system should be used.

(a) Single rows in high plant density



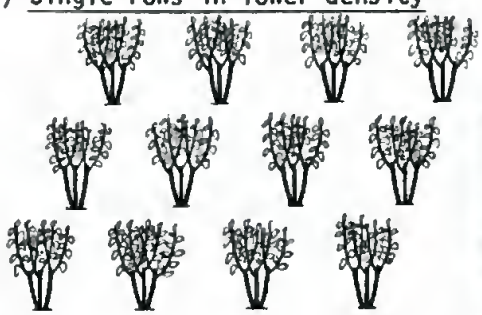
* Convenient for cultivation practice
* Early harvesting after establishment
* Higher yield
* Ideal low-cut pruning

(b) Rows with paired plants



* Some inconvenience for cultivation practice
* More trees in unit area
* Earlier harvest, higher yield than in single-row system

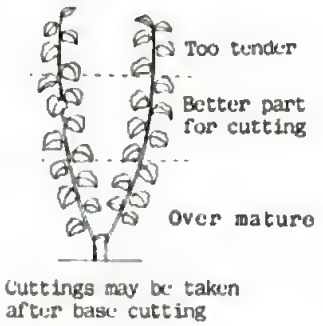
(c) Single rows in lower density

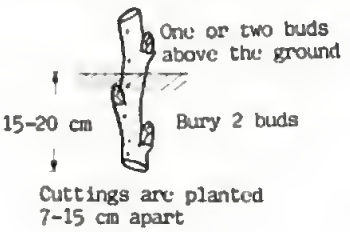


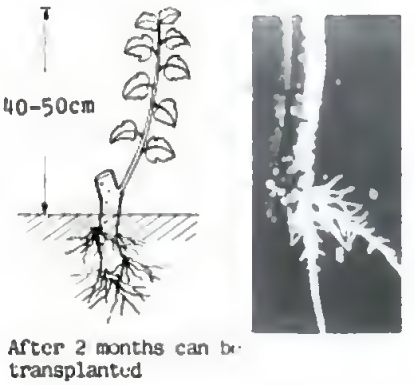
* Convenient for mechanical operation
* Late first harvest after establishment
* Lower yield
* Better for medium or high cut

1.3.3 Planting Practice in Tropical Areas: The high temperatures, humidity and rainfall of the humid tropical zones together with the humus-rich soil make ideal conditions for the ready rooting of cuttings. There are many local varieties which root well under these conditions. Semi-hardwood cuttings may be used to produce saplings.

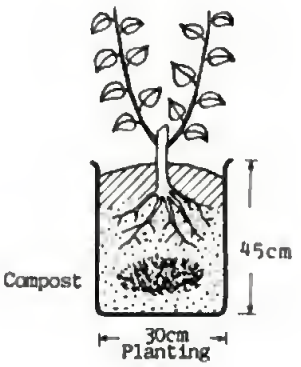
(a) Semi-hardwood cutting: In monsoon climates the best time to strike cuttings is during the rainy season. If ample water is available throughout the year then this method may be used at any time. The following diagrams set out the stages in this method.



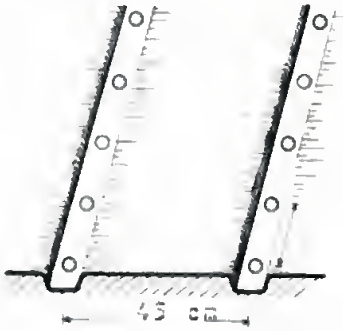




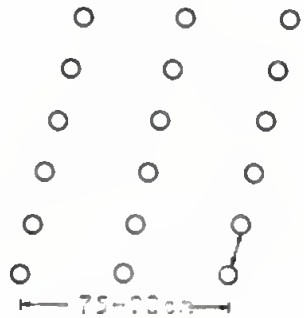
(b) Planting: During the rainy season, the cuttings can be planted directly in the field though even in this case trenches with compost will improve survival and further growth.



(c) Spacing: A number of spacing systems are practised, however the pit (B) and the row (A) systems are the most common. The former allows greater density of planting and therefore higher productivity but the latter permits mechanical operations. The choice will depend on physical and cultural conditions.



(A)



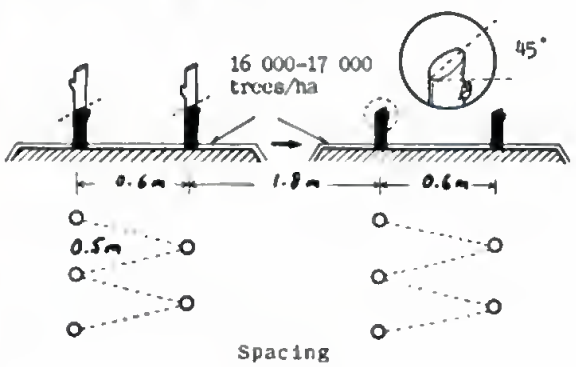
(B)

45-90 cm

1.3.4 Spacing Methods according to Cutting Method (1.3.7)

	Form	Type	Row spacing (m)	Plant spacing (m)	Remarks
Temperate area	Low cut	Single row	1.5-1.8	0.5-0.8	Old type
		Rows with paired plants	Wide ridge: 1.8 Narrow ridge: 0.6	0.5	Now recommended
	Medium cut	Single row	2.0-2.5	0.8-1.2	
Tropical area	Low cut	Pit system Row system	0.9-0.75 0.45-0.6	0.9-0.75 0.5-0.6	

1.3.5 Vinyl Mulching and Dense Planting Practice for Early Harvest: In temperate and sub-tropical zones mulching under vinyl will increase soil temperature, maintain soil moisture and suppress weeds, giving a higher yield than with open planting systems. It will also allow a denser planting system, higher productivity and comparatively easy management making a highly recommended method in most cases. Diagram below shows spacing system suited to this method of planting.



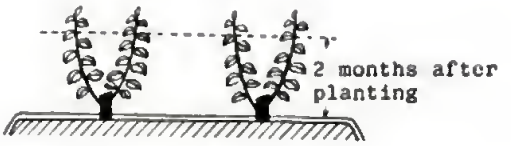
Spacing

Mulching with vinyl (0.018-0.03mm)

Branching after topping

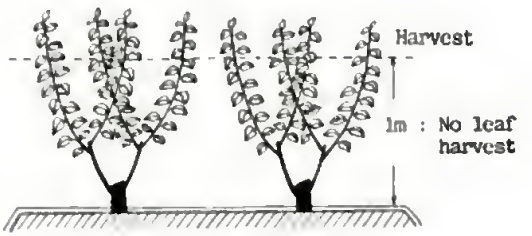
After the first year's harvest

After second year harvest



Topping

* Improved conditions make topping possible in order to develop better branching during the first year of planting.



The first year harvest

* Shoots above 1m are harvested; leaves are left on lower branches to ensure better growth the following year.

1.3.6 Cultivation of Sloping Lands: Sloping lands provide marginal conditions for mulberry cultivation because of poor soil, susceptibility to erosion and physical conditions of working the terrain. These factors must be taken into consideration when deciding whether to develop such land.

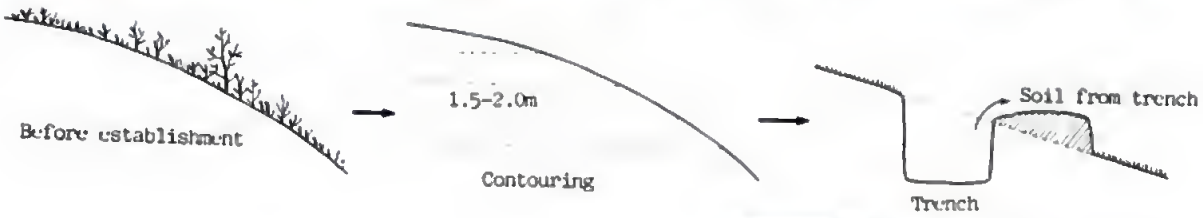
(a) Terrace development: The design of terrace rows is an important factor.

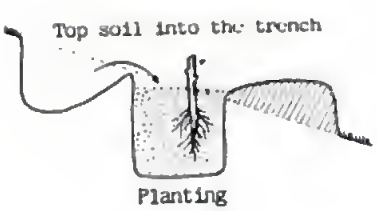
Established field on a slope

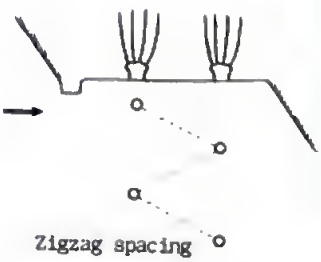
Reclamation of a slope

Trenches along the contour

Planting on a slope



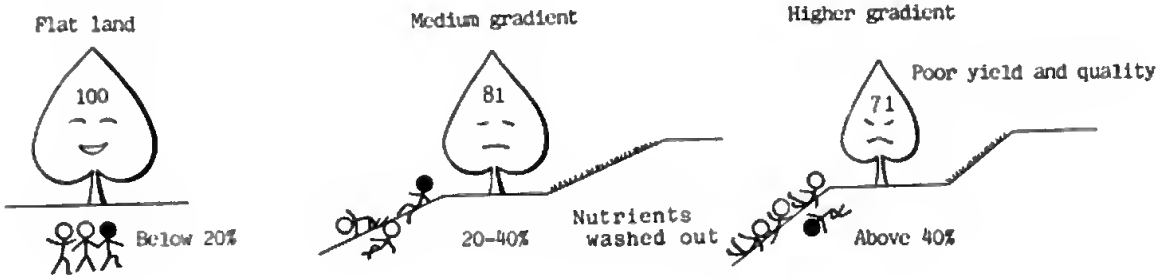




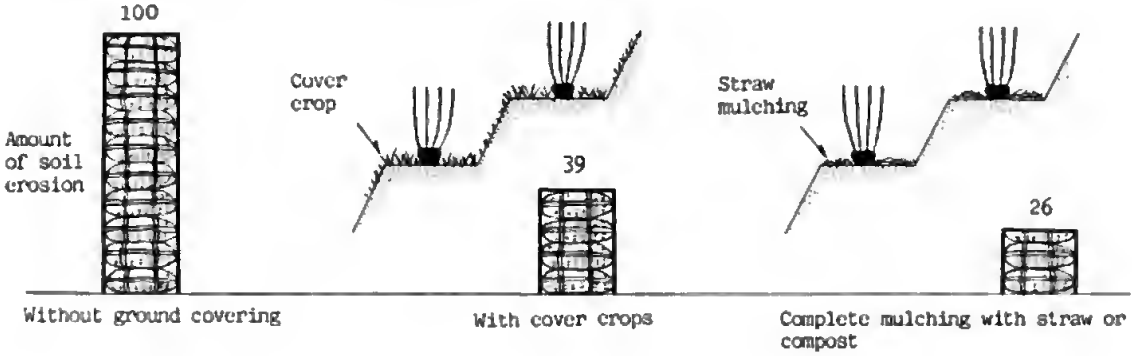
Terrace after establishment

(b) Cultivation practice: Soil erosion and nutrient loss caused by leaching and by being washed out can be minimized by applying an effective covering and by proper fertilizer practice.

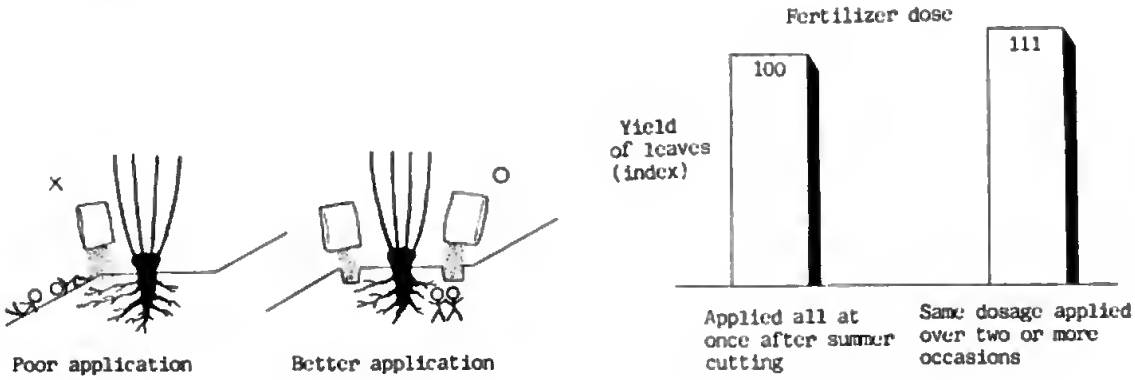
* Productivity according to gradient



* Reduction of soil erosion by effective covering



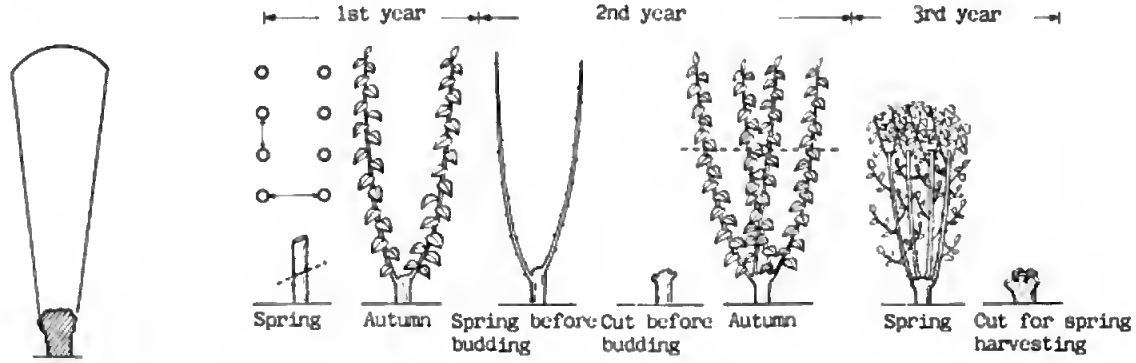
* Application of fertilizer



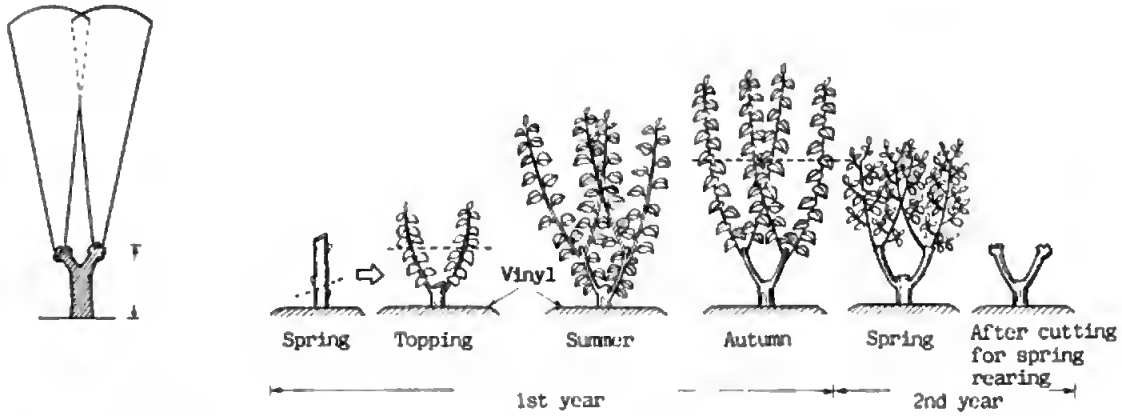
1.3.7 Shaping: The shaping method adopted will determine the quantity of leaves but that in turn is dependant on spacing and harvesting methods and on the level of technical skill of the workers.

(a) Types

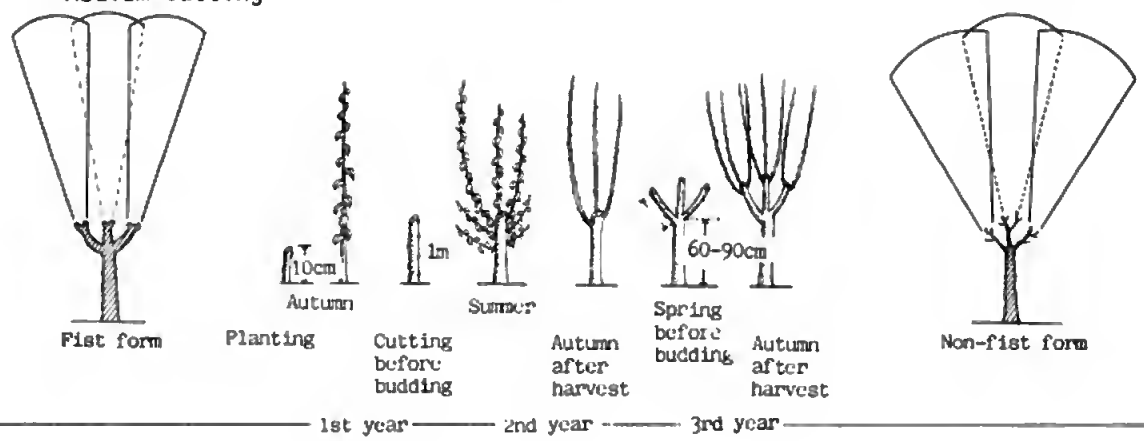
* Low cutting form ('bush type'). This method is generally recommended, except where heavy rain or snow are common (causing the lower leaves to deteriorate).



* Semi-low cutting form



* Medium cutting



(b) Pruning method: Proper pruning method is important to maintain a good head for effective branching. Good branching will produce higher yields and a trained head will improve physical conditions for cultivation practice. The following illustrations demonstrate the effects of good and bad pruning.

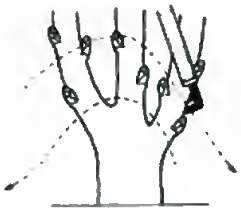
Rapid sprouting and more good branches

Good pruning

Slow sprouting and poor branches

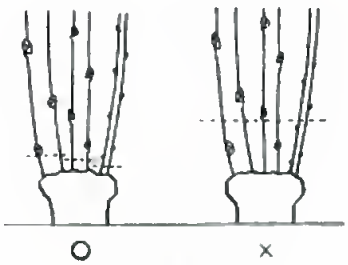
Bad pruning

* Pruning types

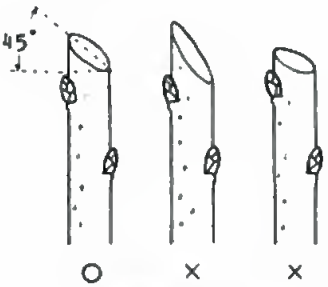


Fist form		Non-fist form
Activated latent buds	Buds for branching	Normal buds
Close to the base	Where to cut	10cm above stem base
Fewer but more vigorous	Number/growth of branches	Many branches but poorer
Easy for training and pest control	For cultivation practice	Difficult to maintain form

* Pruning techniques



Prune branches on different levels



Cutting angle and direction according to the bud position

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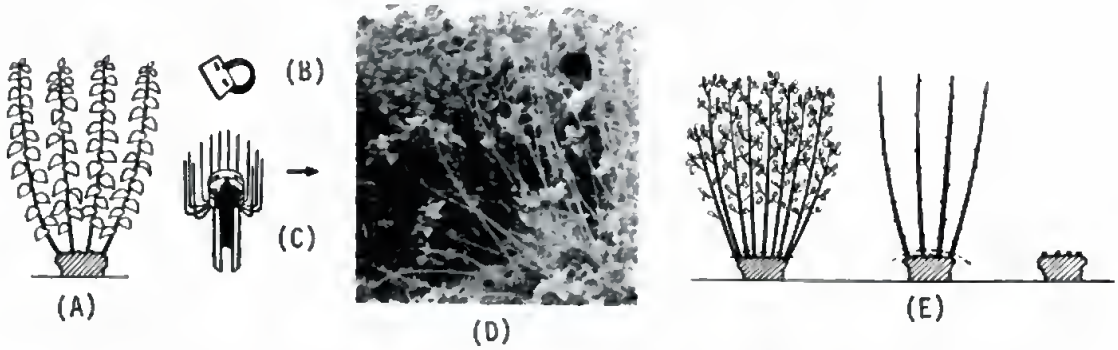
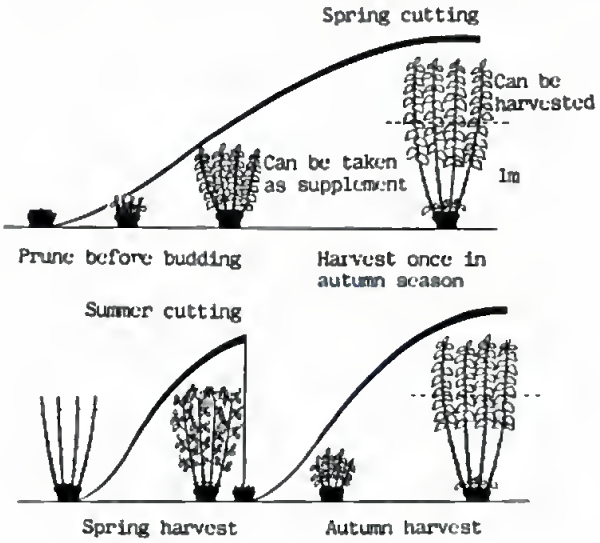
1.4 HARVESTING

1.4.1 Harvesting Methods: Two methods of harvesting mulberry leaves are practised with the choice depending on natural conditions, rearing methods, harvest labour etc. The end use of the leaf is also a crucial factor -- the picked shoots and leaves are fed to young larvae and the branches to advanced larvae.

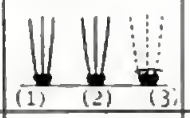
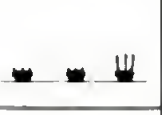
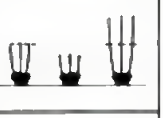
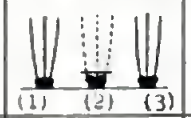
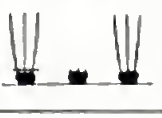
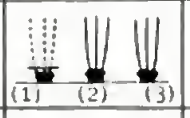
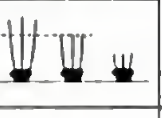
(a) Leaf picking: This extremely labour intensive method takes two forms -- leaf picking in summer and autumn (A & D) and shoot plucking in the spring rearing season (E). Special tools for leaf picking are a finger blade (B) for cutting the leaf and a spike frame for holding the leaves (C).



(b) Branch cutting: Continual branch harvesting will adversely affect the physiological condition of the mulberry and in order to prevent deterioration of the plant cutting should be varied in order to allow its vigour to be maintained.



Branch harvesting system with various combinations to ensure plant vigour

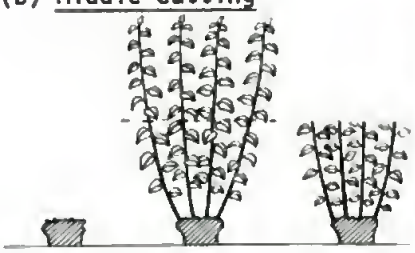
		Before budding	Spring	Summer	Autumn	Remarks
A 3-year rotation between rows in a field	1st year					Vigour of the plant can be maintained by alternation of spring and summer cuttings between rows within a field
	2nd year					
	3rd year					Rotate to 1st year
Alternation between branches on one tree						Usually applied to the trees in medium and high cutting

1.4.2 Branch Cutting Methods: This method is recommended because of its lower labour demands. Harvesting practice depends on rearing season and method, physiological condition of the plant, labour efficiency and the development of new shoots.

(a) Base cutting

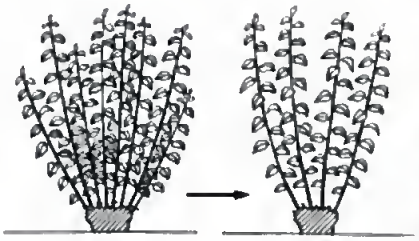
* For spring rearing season
* Followed by leaf harvest from new shoots in autumn

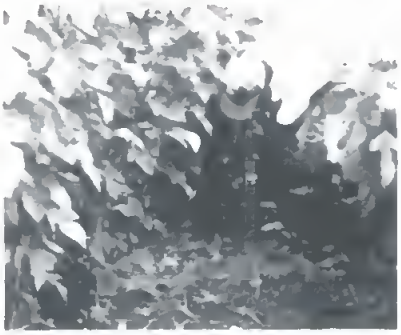
(b) Middle cutting



* For autumn

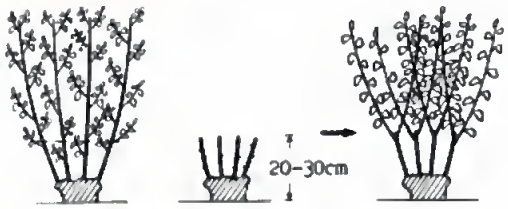
(c) Thinning





* For early autumn rearing
* More often applied when secondary sideshoot development not recommended
* Labour cost high

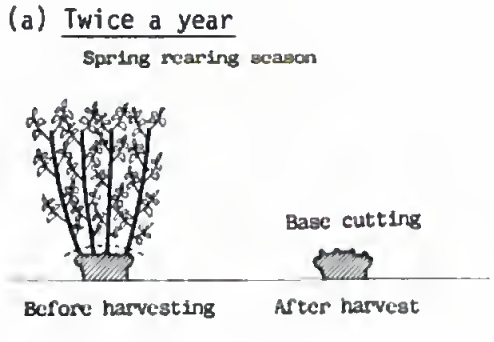
(d) Low cutting with short butts: This method and the following will alleviate the adverse effect of base cutting on the root system.

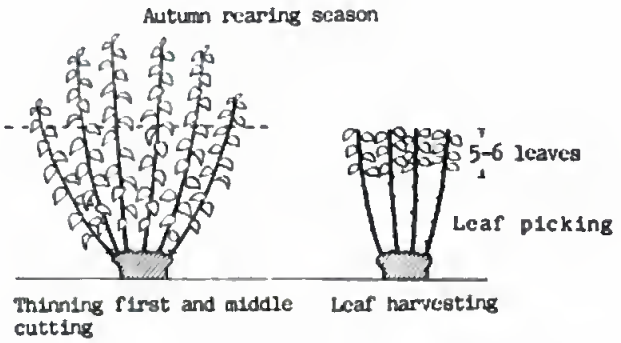


(e) Base cutting leaving one branch: This method will increase branch development; the remaining branch may be cut when new shoots sprout.

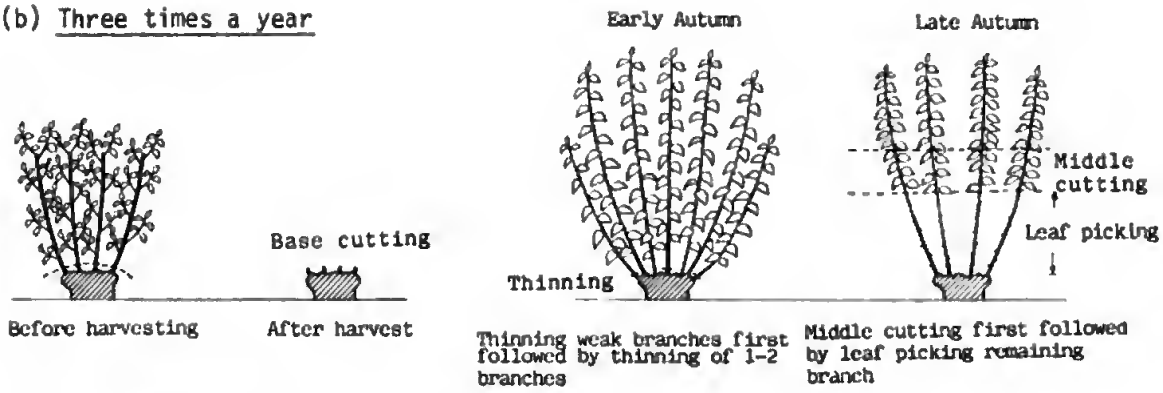
1.4.3 Frequency of Branch Harvesting: Alternation of harvesting methods will minimize stress on the plant and reduce labour costs without causing a serious decrease in the yield in temperate zones. The two methods are mutually exclusive and each has a different physiological effect.

(a) Twice a year





(b) Three times a year

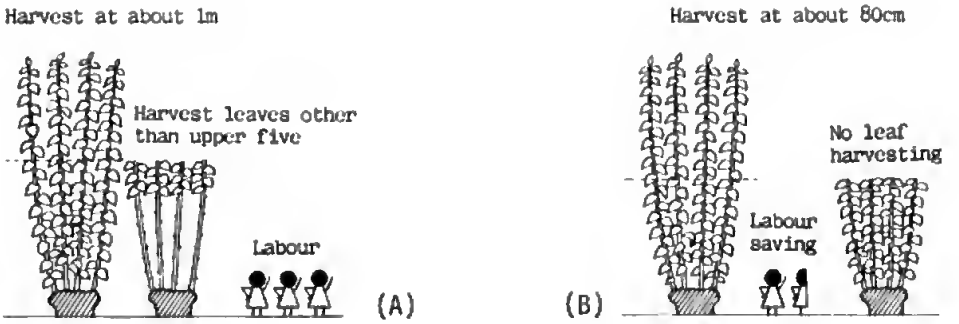


(c) Four times a year

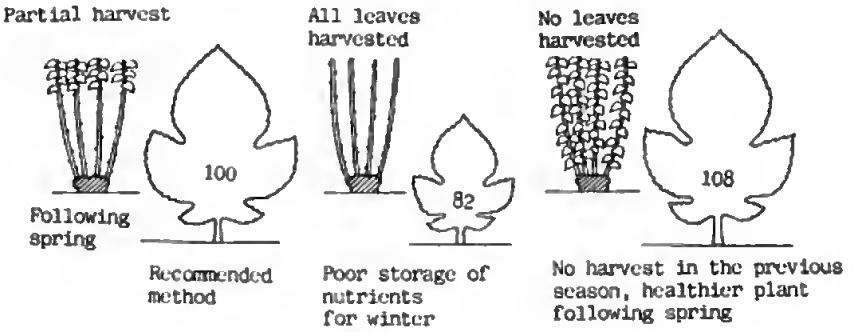
	Before sprouting	Early spring harvest (1)	Late spring harvest (2)	Early autumn harvest (3)	Late autumn harvest (4)	Next year
Block I	1m	Base cutting		Thinning and medium cutting		Apply block II
Block II			Base cutting	Thinning	Medium cutting	Apply block I

1.4.4 Branch Harvesting for Autumn: Though harvesting causes an interruption to the normal growth of the plant, by combining branch harvesting and leaf picking in the autumn season it is possible to ensure minimal decrease in yield the following spring. When considering whether to adopt this system several factors should be looked at -- development of new shoot, yield in the following season, leaf quality and labour cost. Autumn branch harvesting will not cause decreased yield the following spring because most of the remaining buds will sprout, spring sprouting will be promoted and new shoots will flourish.

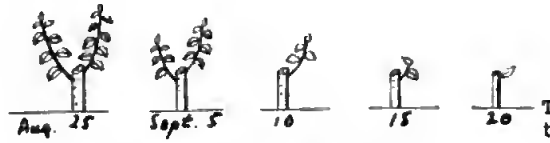
The following diagrams show combined branch harvesting and leaf picking (A) and branch harvesting only (B). The latter reduces the labour demand by one half but the yield is also less and does not include a leaf harvest.



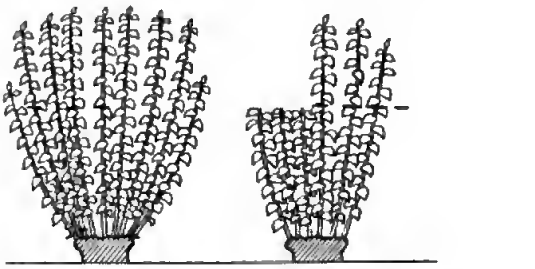
The effect of specific systems of harvesting on leaf yield the following spring is shown in the following diagram. The continual harvest of all leaves will gradually cause significantly lower yields and will reduce the health and strength of the plant.



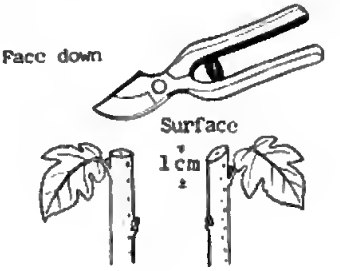
Useless sideshoot development in autumn following harvest can be minimized by adopting appropriate cutting and timing methods. At branch cutting A shows the differences in sideshoot development depending on harvest. At partial harvest weak branches should be cut (B).



(A) Branch cutting time

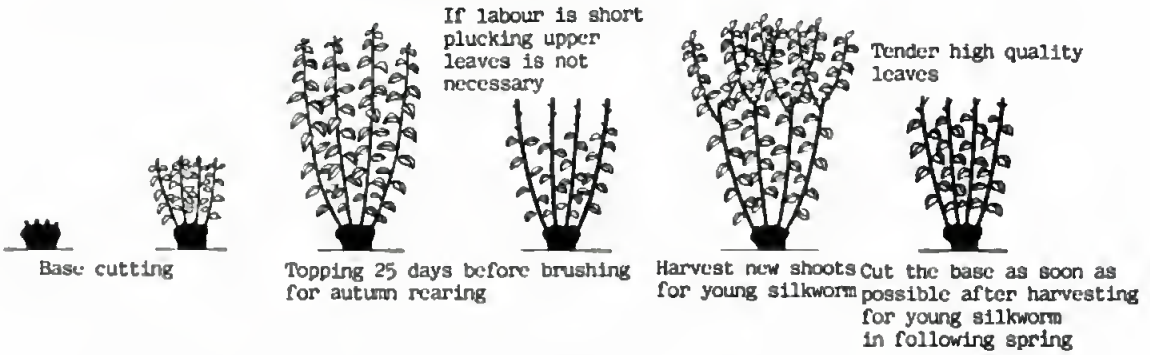


Correct cutting method will minimize mechanical damage -- use shears with cutting blade face down as shown in accompaning illustration.

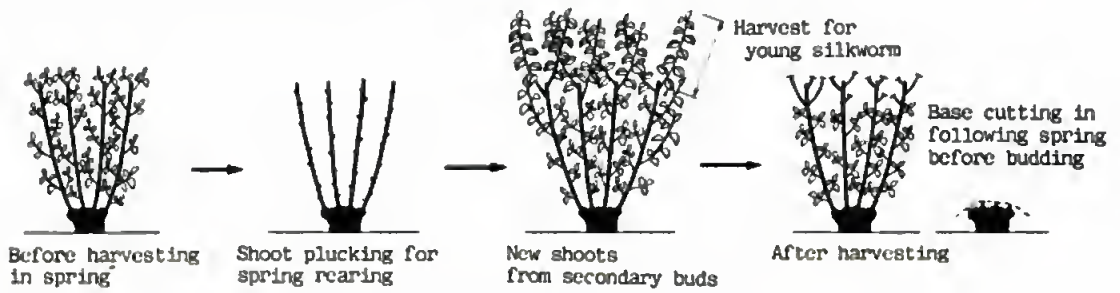


1.4.5 Pruning Method for Early Instar Silkworms: Spring season growth provides tender young leaves, however to produce tender quality leaves for the young silkworms in autumn when it is vital to ensure good cocoon yield, it is necessary to adopt special methods to provide new shoots. This applies only to temperate zones as in tropical zones seasonal differences are minimal.

(a) Topping branches to promote new shootlets



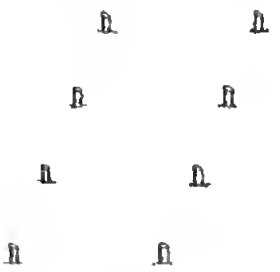
(b) Sprouting of secondary buds after spring leaf plucking



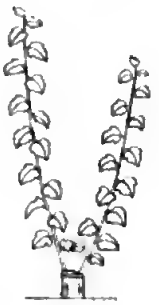
(c) Management of trees for young silkworms: To ensure production of highest quality leaves extra measures should be taken such as those shown below.

1.4.6 Pruning and Harvesting in Tropical Areas: In most tropical areas leaves are harvested by plucking throughout the year. Continuous picking however leads to poorer leaf quality in each subsequent harvest and is labour intensive. Branch harvesting has not been widely adopted.

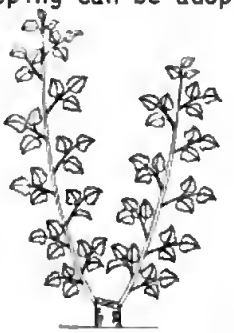
(a) Plant development to first harvest: The following diagrams show the initial development of a mulberry plant to the first harvest. At this stage the tree has reached full development and a programme of multiple cropping can be adopted.



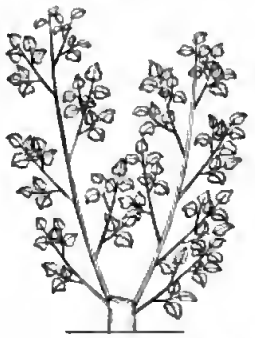
Planting



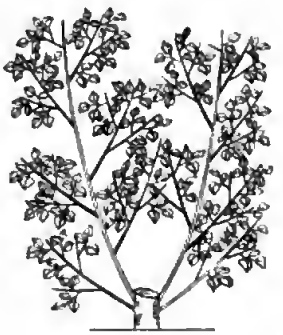
6th month after planting



9th month after planting harvest some leaves for rearing, top for more shoot growth



11th month after planting harvest leaves from secondary branches



15th month after planting harvest tertiary branches

After pruning, leaves can be harvested in 2-3 months, followed by another in 2-3 months

After harvest pruning

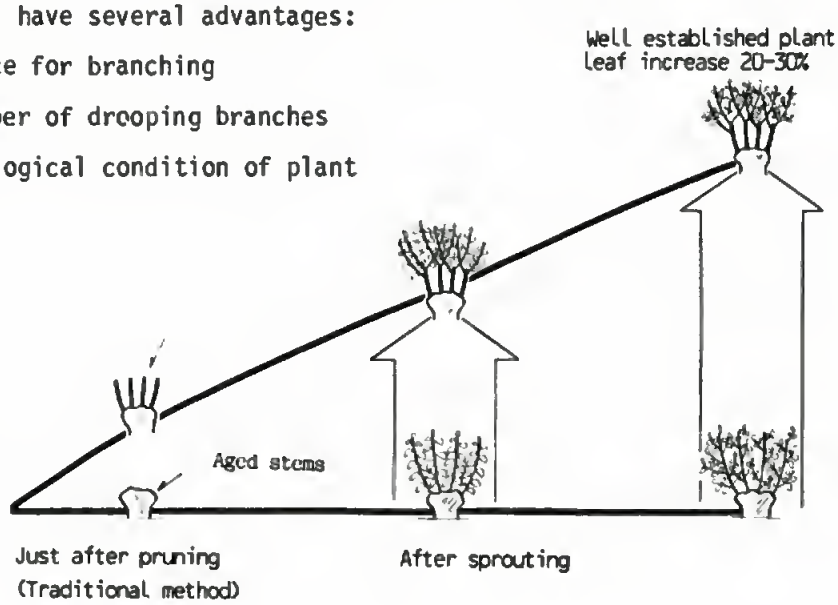
(b) Multiple cropping method: This method is dependent on a number of fields being available. The table below shows how each field is cut according to rearing demands and then given 2-3 months to recover.

Block	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
I												
II												
III												
IV												

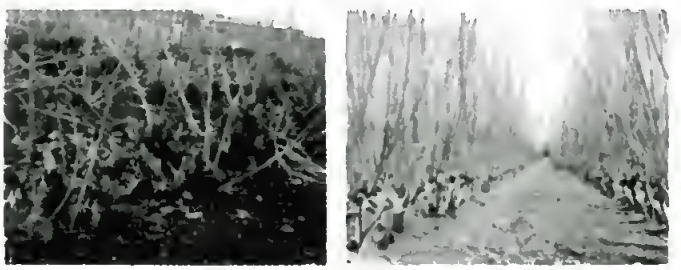
1.4.7 Maintenance of Stem Head: The stem head is that part of the plant from which new branches sprout. The stem head tissue will eventually become enlarged causing lower shooting ability and consequently lower yield. To prevent this, and to maintain the stem head in good condition several methods are recommended.

(a) Low cutting with short butts: Instead of pruning back to the stem head branches are cut back to 20-30cm which will provide a series of new growth points. This will have several advantages:

* Increased space for branching
* Decreased number of drooping branches
* Better physiological condition of plant



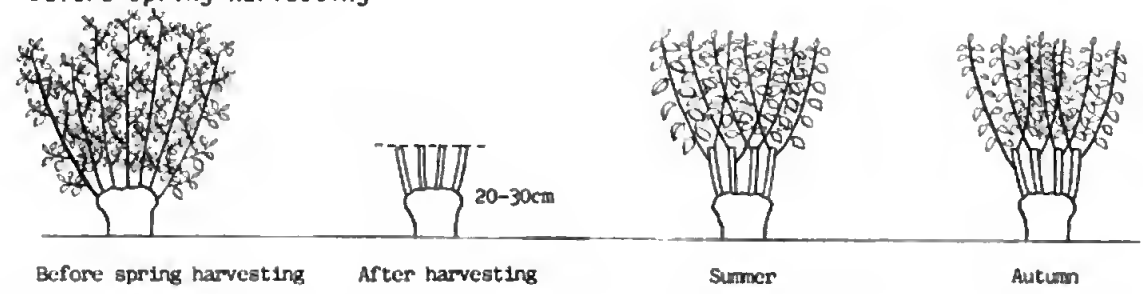
(b) Removal of enlarged tissue: Using a chain saw aged stem head tissue can be cut off quickly and cleanly (A) enabling a new stem head to develop and send out new branches (B).



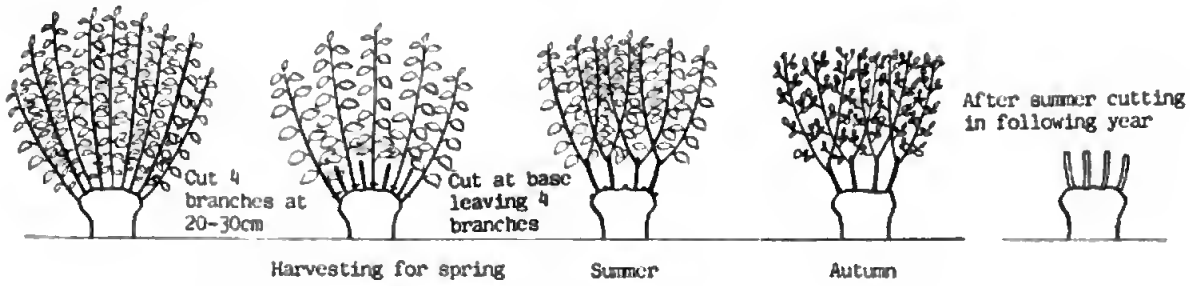
(A) (B)

(c) How to make high stem heads:

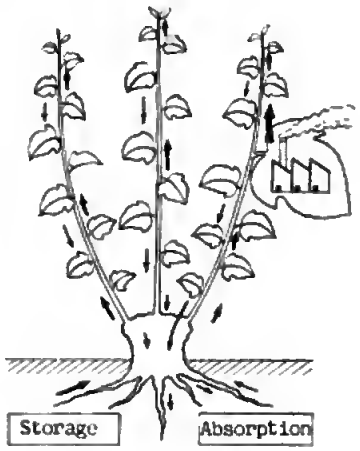
* Before spring harvesting



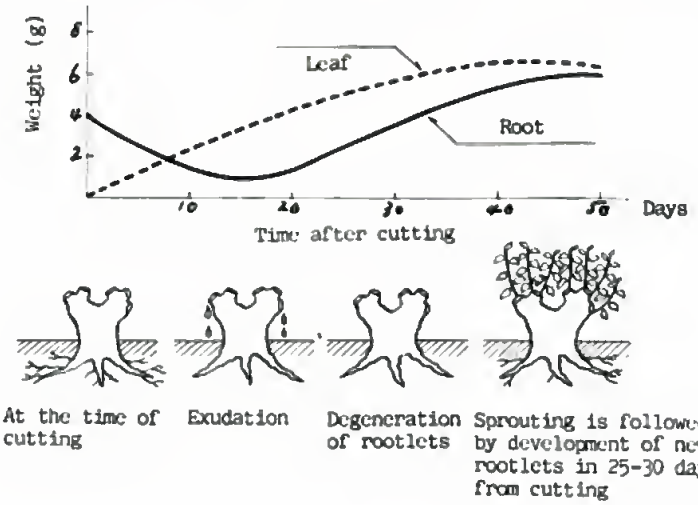
* Before budding



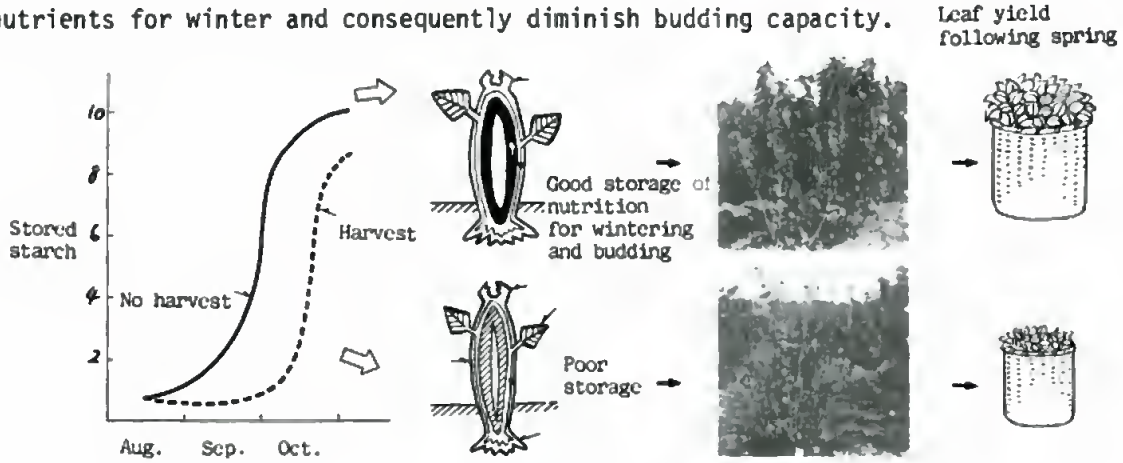
1.4.8 Influence of Harvesting on Physiology: Harvesting causes a drastic loss of plant organ for photosynthesis, consequently a corresponding loss of rootlets leading to a reduction of storing capacity of nutrients needed for recovery. The leaf is the factory for the basic nutrition of the plant (see 1.1.2). During the growing season the roots absorb nutrients and water; in the dormant season they store the nutrients. If the shoots are taken during the growing season the root system will be decreased accordingly. If the leaves are removed, either by branch harvesting or leaf plucking, then the corresponding nutrient loss will lead to a diminished leaf yield the following season.



(a) Root system: The following graph and diagram show the relationship between top and root system after summer cutting. It takes about 45 days for the root system to recover its original condition. By leaving several branches or portion of some branches some of the stress to the plant will be alleviated.



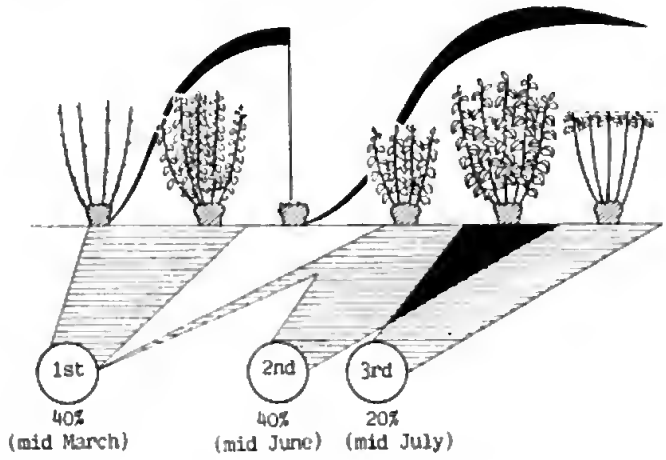
(b) Leaf yield: The following graph and diagrams show the influence of leaf removal on leaf yields the subsequent spring. It will reduce storing capacity of nutrients for winter and consequently diminish budding capacity.

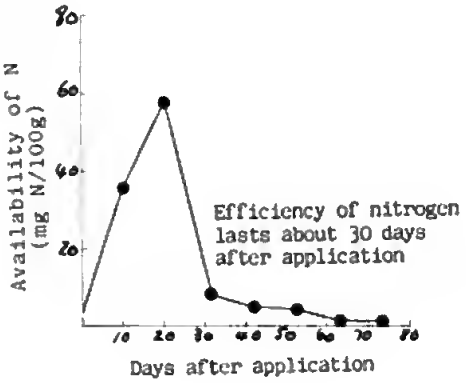


1.5 SOIL CONSERVATION AND MANAGEMENT

1.5.1 Fertilizers: Amount and frequency of fertilizer application depend on growth pattern of plant, pruning and harvesting practice, rainfall, soil type and climatic conditions.

(a) Temperate zones: The following diagram shows the relationship between mulberry growth and the application of fertilizers in Korea. The graph shows the absorbability of applied nitrogen.



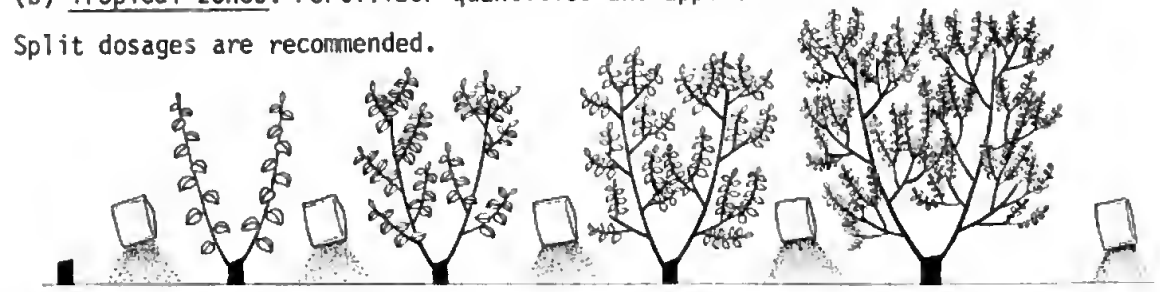


The relationship between desired cocoon yield and the amount and type of fertilizer (including compost) is a direct one as the following table shows. Care must be taken that the relative proportions of the specific ingredients are balanced (see 1.5.2).

(unit : kg/ha)

Desired yield	Nitrogen (N)	Phosphate (P)	Potassium (K)	Compost (t)
800	250	110	150	12
1 000	300	130	180	20
1 200	350	150	200	30

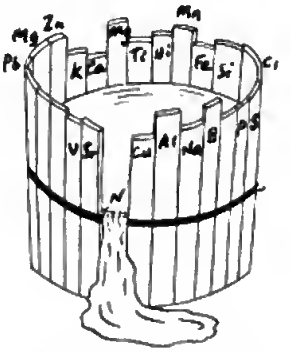
(b) Tropical zones: Fertilizer quantities and application are set out below. Split dosages are recommended.



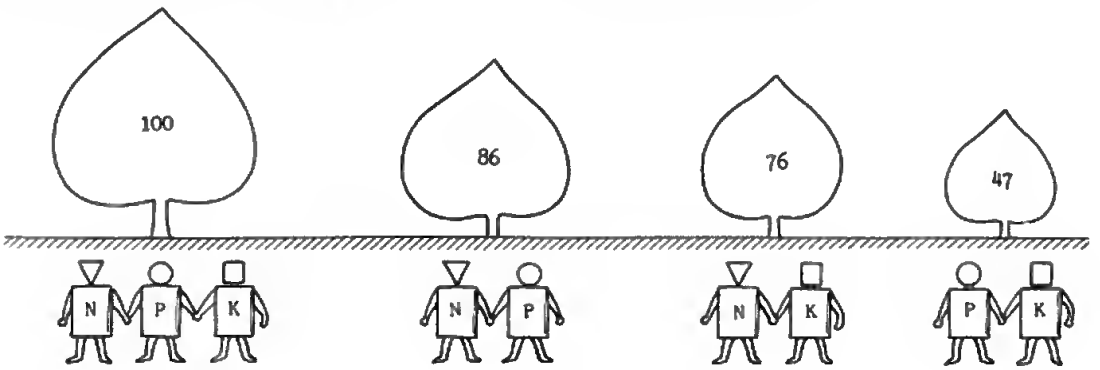
(kg/ha)	I crop	II crop	III crop	IV crop	V crop
Nitrogen	50	50	50	50	50
Phosphate	50		50		
Potassium	50		50		

1.5.2 Fertilizer Application: For both higher yields and better quality leaves the application of a balanced fertilizer is imperative.

(a) Composition: Balanced fertilizer application is important because the yield will be decided by the shortage of the nutrient in most limited supply as the accompanying diagram shows.

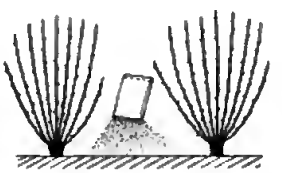


(b) Yield: Balance between the three elements nitrogen, phosphate and potassium, is particularly important. Nitrogen is important for leaf yield, phosphate for leaf quality and potassium for cold resistance and leaf quality.



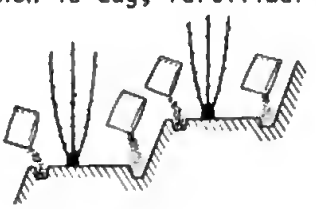
(c) Application methods

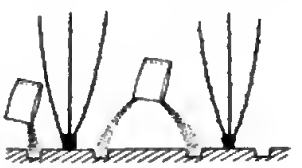
* Broadcasting: On flat mulberry fields the fertilizer is spread between the trees and then the soil and fertilizer are mixed with a scratching tool. Suited to mature trees.



* Band application: Suitable for sloping lands (A) and for younger trees (B). A shallow trench is dug, fertilizer is spread in furrow and covered with soil.

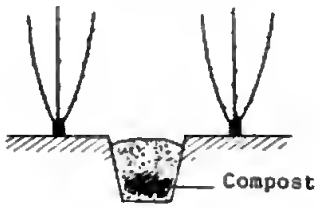
(A)





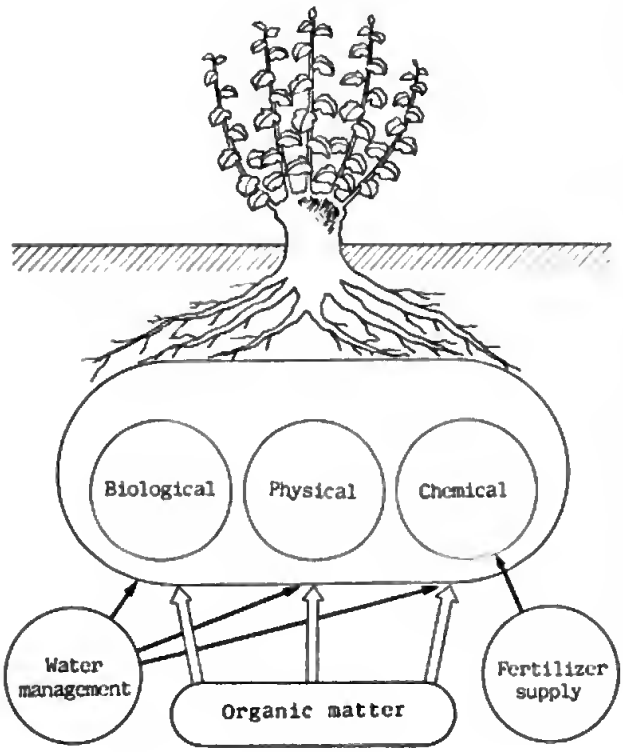
(B)

* Organic matter: Compost is deposited in a trench dug in the interspace between the mulberry rows (A). Straw and green manure can be applied on the surface in the interspace (B).



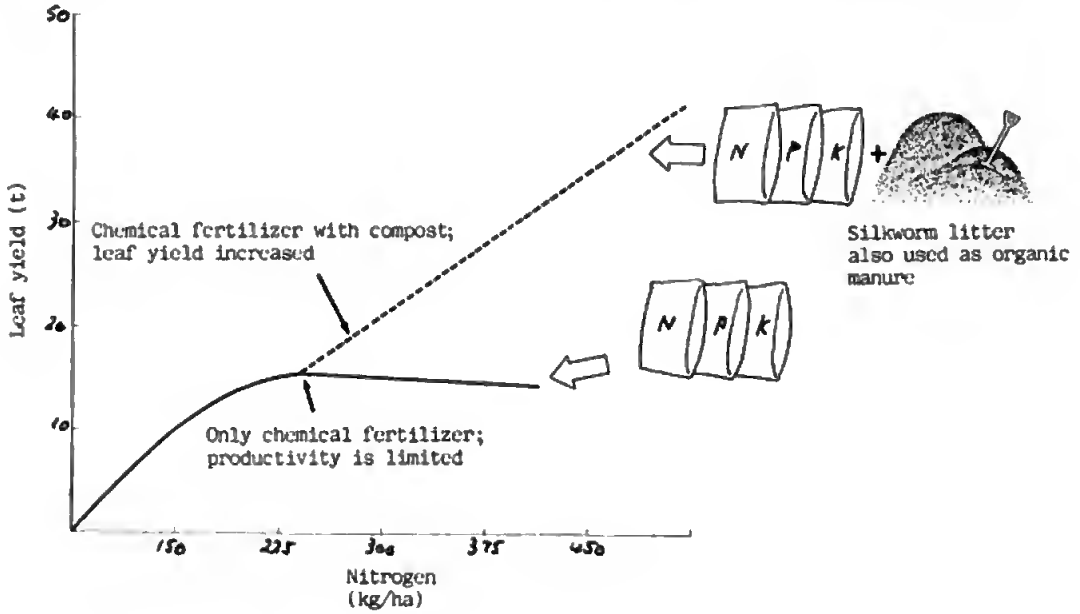
1.5.3 Importance of Organic Matter: Soil fertility is dependent also on humus the annual loss of which is about 2.3t/ha, the equivalent of 12t of organic matter, which must be supplemented to maintain fertility.

(a) Role of humus: For soil to provide optimum conditions for growth the biological, physical and chemical components must be in a state of balance (see diagram below). The table sets out the various functions of humus.



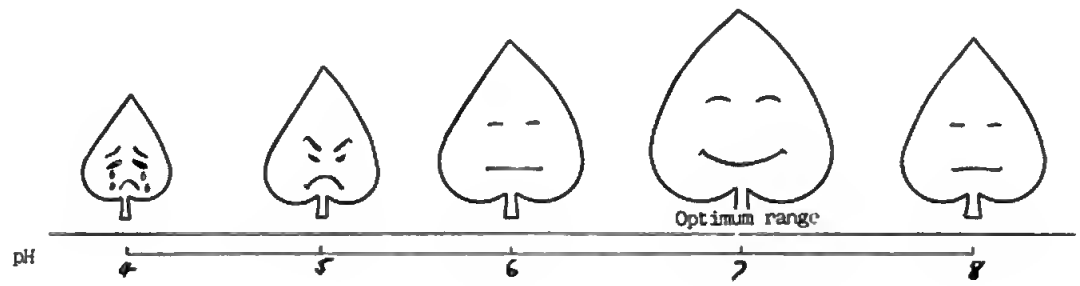
Roles of organic matter
CHEMICAL * Increase nutrient-holding capacity * Supply macro/micro nutrients * Change soil reaction * Decrease P_2O_5 fixation in soil
PHYSICAL * Increase water-holding capacity * Improve soil structure * Change soil colour * Facilitate cultivation
BIOLOGICAL * Improve activity of soil micro-organisms * Improve N_2 fixation * Supply hormones and vitamins to micro-organisms

(b) Effect of compost on leaf yield: The following graph shows the benefit of combining fertilizers with organic matter as measured by leaf yield increase.

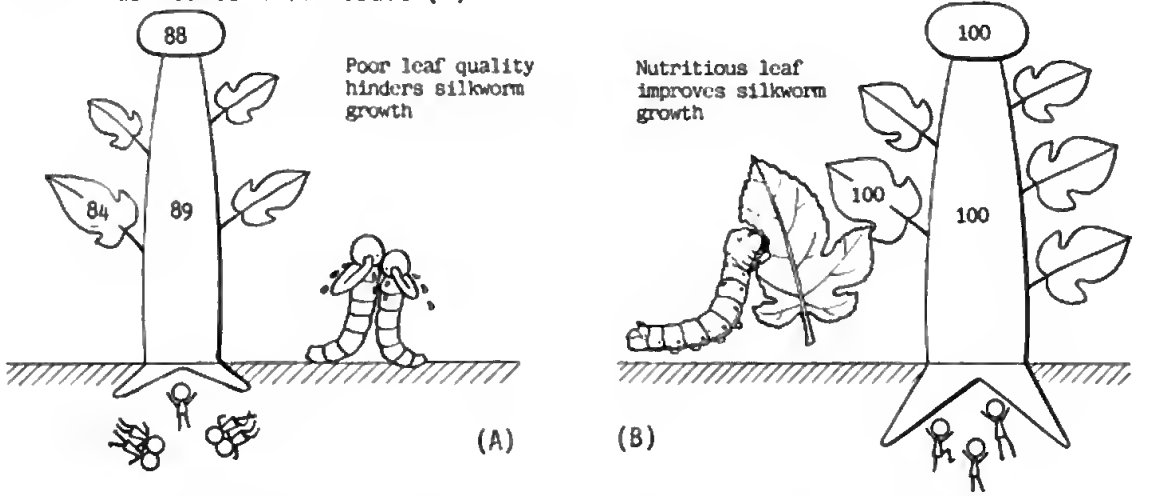


1.5.4 Improvement of Acid Soil: Mulberry trees thrive on neutral soils (pH 6.5-7.0). In acid soils the plant cannot absorb nutrients effectively, causing poor leaf quality with unbalanced leaf composition.

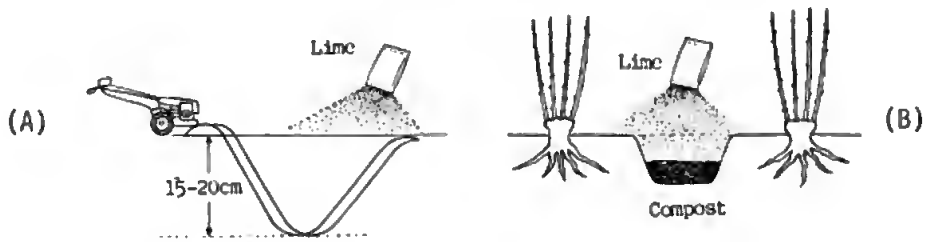
(a) Soil reaction and growth: The following diagram shows the effect of pH content in the soil on the quality of the leaf.



(b) Effect of lime application: Acid soil reduces root activity and nutrient availability causing poor leaf quality (A). With the application of lime, acid soil will be broken down, the root system will work more effectively and more nutritious leaves will result (B).

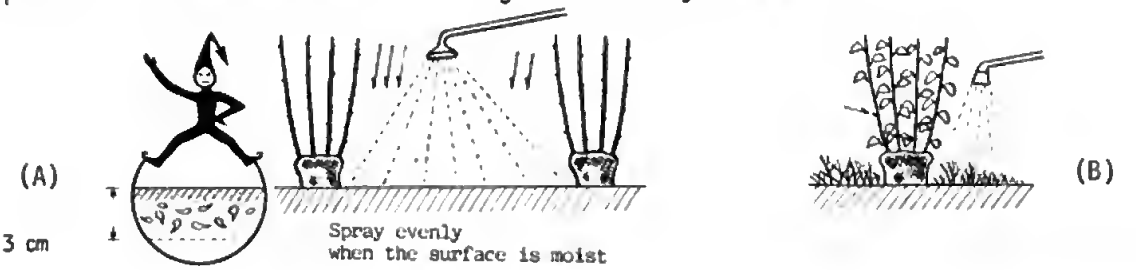


(c) Application: Spread lime evenly over the field, then deep plough (A) or combine with compost and deposit in trench between rows (B).



1.5.5 Weed Control: Weeds compete with crops for nutrients, sunshine and water. Chemical, mechanical or cultural methods may be used to control weed growth, however in each case the choice of method must depend on local factors.

(a) Chemical method: Herbicides may be sprayed on the surface to suppress weed germination (A) or applied on the grown weeds (B) though care must be taken to prevent the chemical from contacting the mulberry leaves.



	Ground application		Foliage application	Remarks
	CAT (WP)	Lasso (EC)	Paraquat (EC)	
Dose Water (l)	1.5-3.0kg 1 000- 1 500	3.0-6.0l 1 000- 1 500	2.0-3.0l 1 000-1 500	Herbicide depends on weed. Application volume depends on moisture/weed growth

(b) Mechanical method: Plough between rows either before budding (A) or after summer cutting (B) then apply herbicide spray (C). Do not use after sprouting.

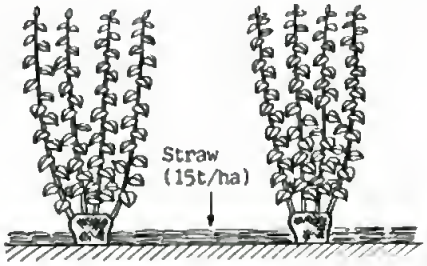
(A)

(B)

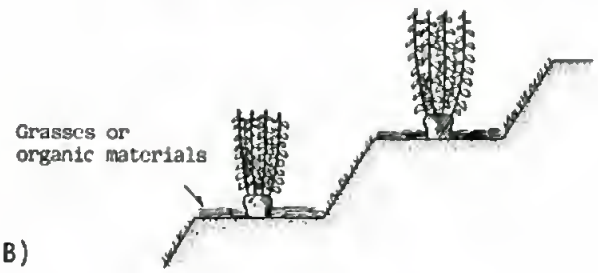
+

(C)

(c) Cultural method: Straw and other organic matter is placed around the trees effectively preventing weeds from growing because of lack of sunlight (A). This method provides much needed humus to the soil and is particularly suited to sloping lands where it has the additional effect of retaining the soil (B). If insect pests breed in the mulch it should be treated with insecticides.



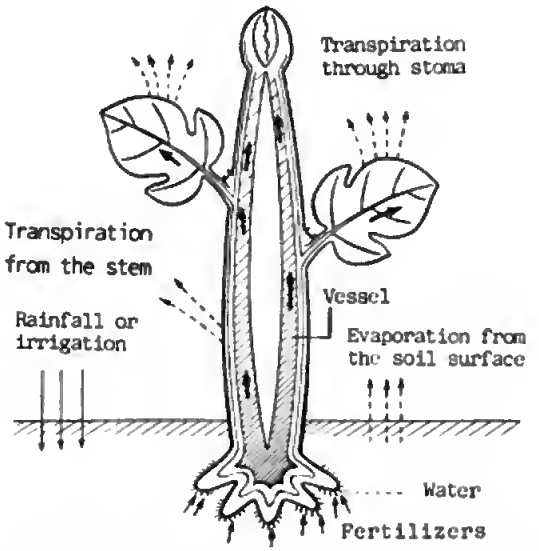
(A)



(B)

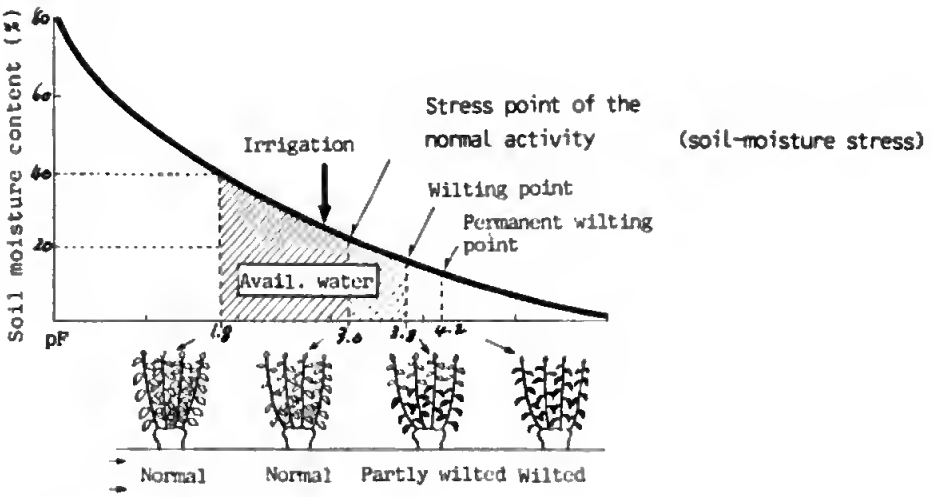
1.5.6 Water Management: Average daily rainfall of 4-5mm is required during the growing season. Irrigation is needed if rainfall falls below this level.

(a) Plant water consumption: The following diagram shows how water is absorbed and used by the mulberry plant, and more generally how water accumulates and is dispersed.



The lower the holding capacity of the soil the greater the amount of water to drain through the profile and the more prone to drought the soil will be

(b) Soil moisture content



PF = Potential Force = log Hmbar of water column.
Example: $PF^3 = 10^3$ mbar.

(c) Water conservation

* Direct method: The following diagram demonstrates the variety of methods available.

Irrigation

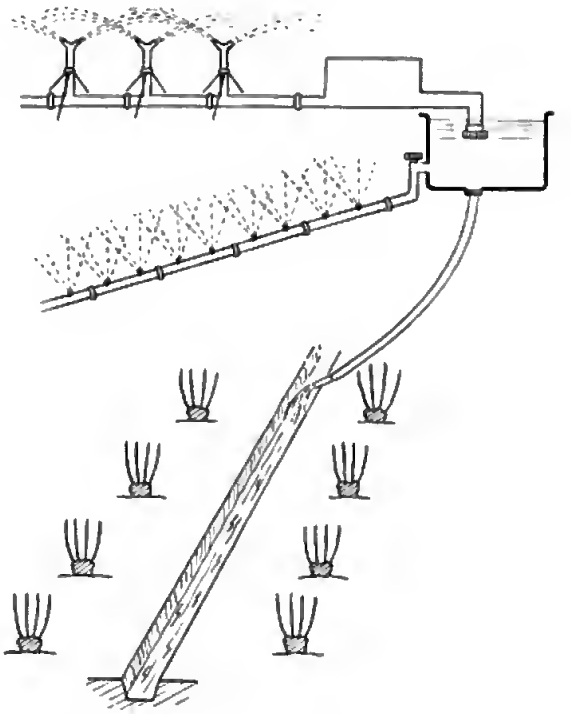
200-250t/ha every 4-5 days

Sprinkler

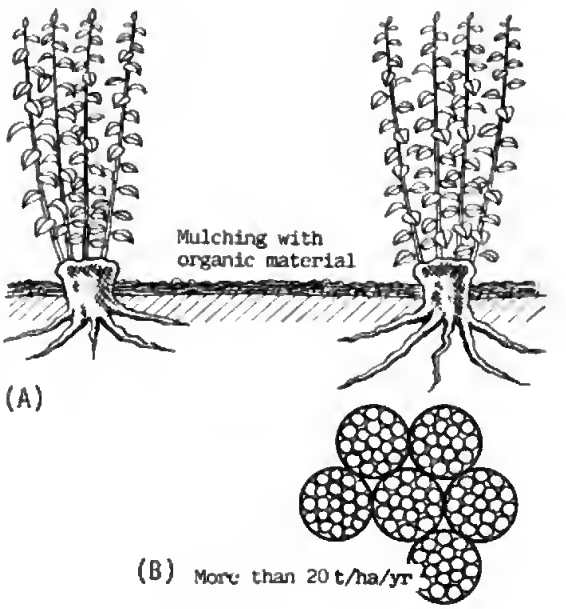
Ideal but costly

Furrow method

Low cost but some waste of water



* Indirect method: Mulching the surface of the soil will suppress evaporation and the organic matter will increase the water holding capacity of the soil (A) by enhancing aggregation of soil particles (B).

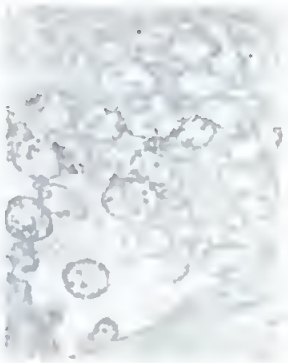


Chapter 2: MULBERRY DISEASES AND PESTS

2.1 DISEASES

2.1.1 Dwarf Disease (Mycoplasma-like Organism -- MLO)

(a) Symptoms: In early June the leaves become crumpled and yellowish (A), growth ceases, shoots develop slender laterals. The disease cycle continues during the crop season and within two or three years infected plants die. B shows micrograph of MLO in phloem tissues of branch.

(A)  (B)

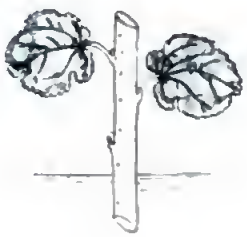
(b) Favourable conditions

* Field with infected trees
* Propagation of mulberry saplings near infected fields
* Poor drainage
* Over-dressing of nitrogen fertilizer

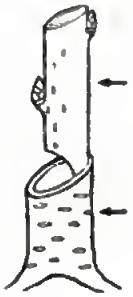
(c) Transmission of pathogen: Transmission is by propagation or by vector.

1. Propagation of saplings: either by softwood cuttings or by grafting

* By using infected shoots

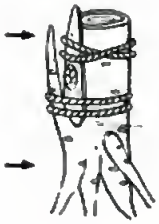


* By using infected scion or root stock



Infected scion will transmit pathogen to new plant but outbreak of disease depends on collecting time of scion.

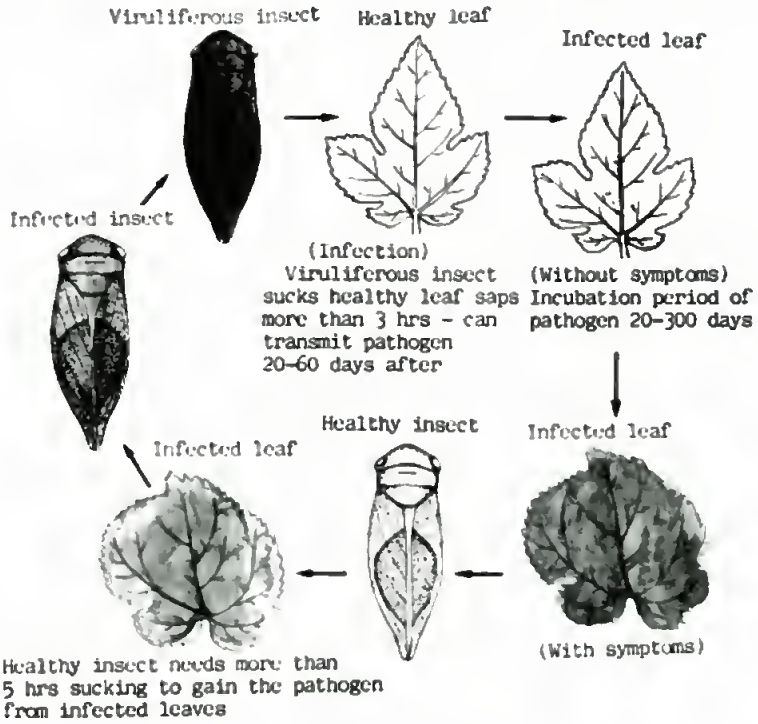
Root stock infected with mycoplasma 100% disease outbreak in new plants.



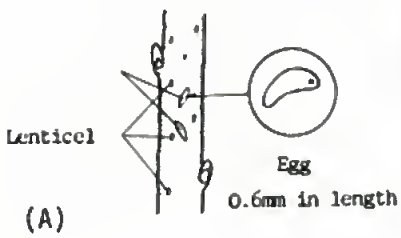
2. Vectors (Leaf Hopper) Hishimonus sellatus Uhler

Hishimonoides sellatiformis Ishihara

The following diagram shows cycle of infection through insect vectors.



* Life cycle of insect vector (Hishimonus sellatus)



(B)

* 3-4 generations per year.

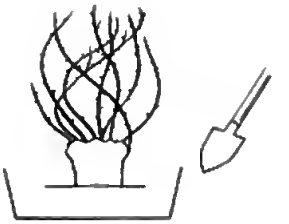
* Overwinter as eggs inside bark (A).

* Newly-hatched nymphs suck juice from buds and leaves.

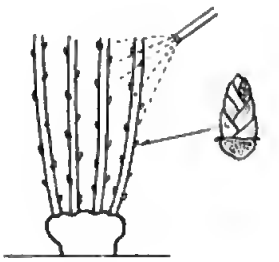
*(B)shows adult and nymph.

(d) Control measures

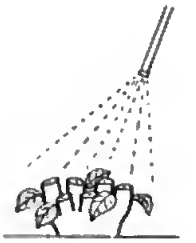
* Dig out diseased trees and plant healthy saplings



* Spray to eliminate hibernating eggs and nymphs (see below for chemical applications)



* Spray stumps after summer pruning (see below for chemical applications)



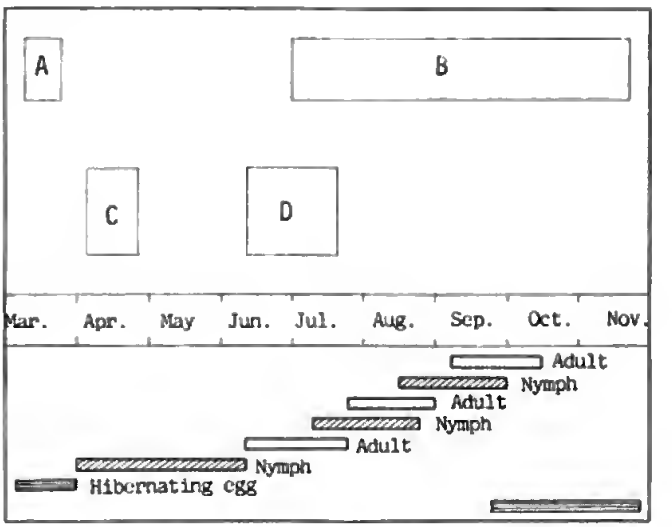
* Control measure calendar

A Dig out diseased trees and replace with healthy saplings

B Dig out diseased trees

C Control hibernating eggs with chemical spray (Cidial 47.5% EC 1:1 000, 1:3 000l/ha)

D Control nymphs and adults with chemical spray (Cidial 47.5% EC 1:1 000, 1 300l/ha Thiolix 3% D 40kg/ha)



2.1.2 Twig Blight Gibberella moricola (Cesati et de Notaris) Saccardo [Fusarium lateritium Nees f. sp. mori(Desmazieres) Matuo et Sato)]

(a) Symptoms: In the spring season dark lesions appear around the winter buds and upper part of the branches cut during the previous season. The lesions expand and a reddish sporodochial formation appears (A). Upper part of infected branches slowly wither and 2-3 months later perithecium forms on the lesion (B).

(A)

(B)

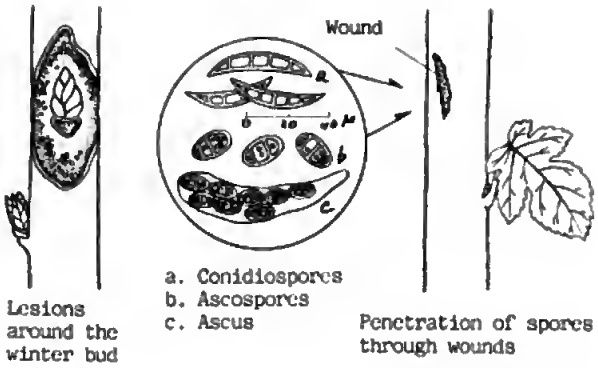
(b) Favourable conditions

* Wounds on plant caused by leaf picking and branch cutting in autumn rearing season
* Wounds caused by insects such as Mulberry Borer (A) and Mulberry Minute Bark Beetle (B)

(A) (B)

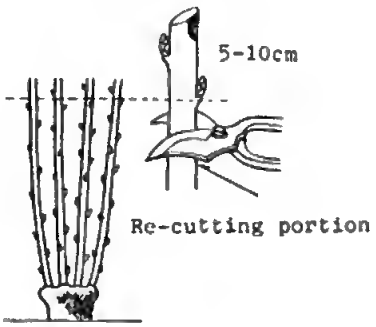
* Over-dressing with nitrogen fertilizer

(c) Disease cycle

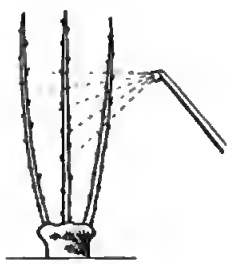


(d) Control measures

* Re-cut branches in winter to remove wounded sections of branches



* Spray with fungicides after autumn rearing season (use Captan 50% WP 1:200, 1 500l/ha or Topsin-M 70% WP 1:500 , 1 500l/ha)



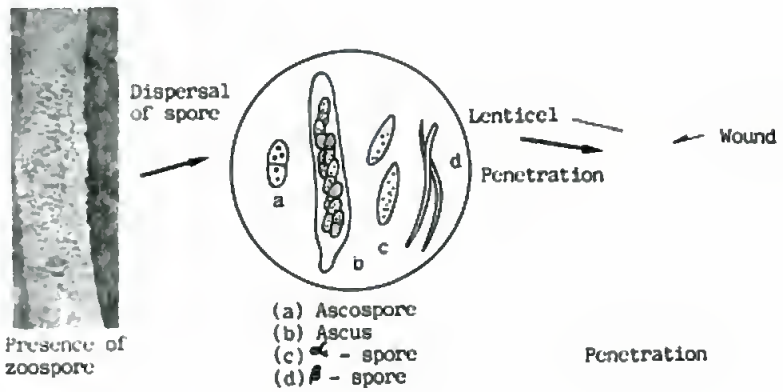
2.1.3 Die-back, Dogare Blight Diaporthe nomurai Hara

(a) Symptoms: In the spring season, dark brown lesions appear on middle or lower parts of branches (A) and, later, pycnidia are formed (B).

(b) Favourable conditions

* Low cut mulberry field
* Field with infected trees
* Heavy snowfall area
* Presence of wounds
* Excess consumption of nutrients by re-sprouting in autumn season

(c) Disease cycle



(d) Control measures

* Avoid over-dressing with quick release nitrogen fertilizer
* Spray with fungicides after autumn rearing October-November (Topsin-M 70% WP 1:500-1 000, 1 300l/ha)

2.1.4 Bacterial Blight *Pseudomonas mori* (Boyer et Lambert) Stevens (*Bacterium mori* Boyer et Lambert)

(a) Symptoms: Small spots, dark brown turning to black, form on the leaves (A). Infected leaves curl and roll up (B); new shoots rot and secondary branches form beneath the lesions.

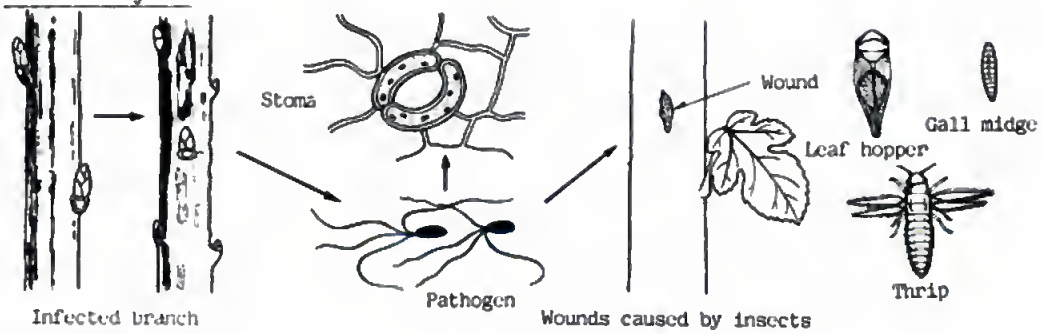
(A)

(B)

(b) Favourable conditions

* Negligent care of infected branches
* Dense planting of field
* Over-dressing of nitrogen fertilizer
* Rainy season
* Wounds caused by typhoons or by insects

(c) Disease cycle



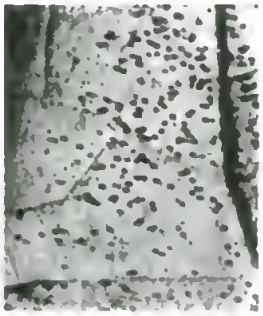
(d) Control measures

* Eliminate infected new shoots and branches
* Spray bacteriocides during summer (Agretomycin 20% WP 1:500-1 000, 1 500l/ha)

2.1.5 Powdery Mildew Phyllactinia moricola (P. Hennings) Homma

(a) Symptoms: Mycelia and conidia cover back of leaf surface (A). Later, yellow cleistothecia appear on the lesions finally becoming black (B).

(A)

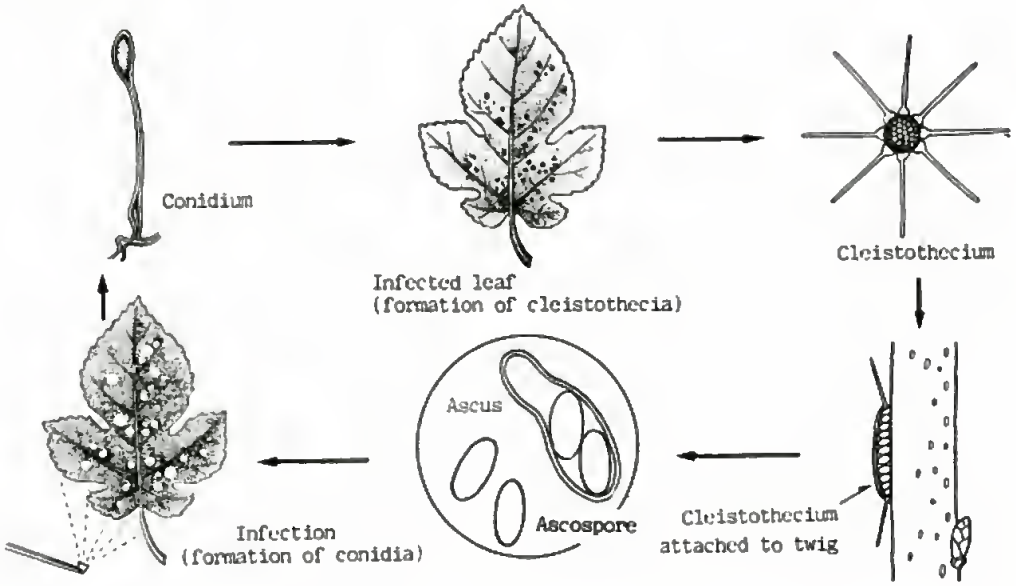


(B)

(b) Favourable conditions

* Cultivation of susceptible variety
* Dense planting

(c) Disease cycle



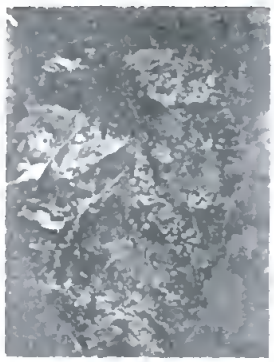
(d) Control measures

* Avoid dense planting
* Chemical spray early spring (Dithane Stainless 58% WP 1:200, 1 300l/ha)
* Chemical spray at first symptom (Topsin-M 70% WP 1:500, 1 500l/ha)

2.1.6 Rust *Aecidium mori* Barclay

(a) Symptoms: Yellow aecidium forms on new bud and leaf surface (A). Yellow aecidiospore visible on aecidium. New buds black rot and wither after infection (B).

(A)

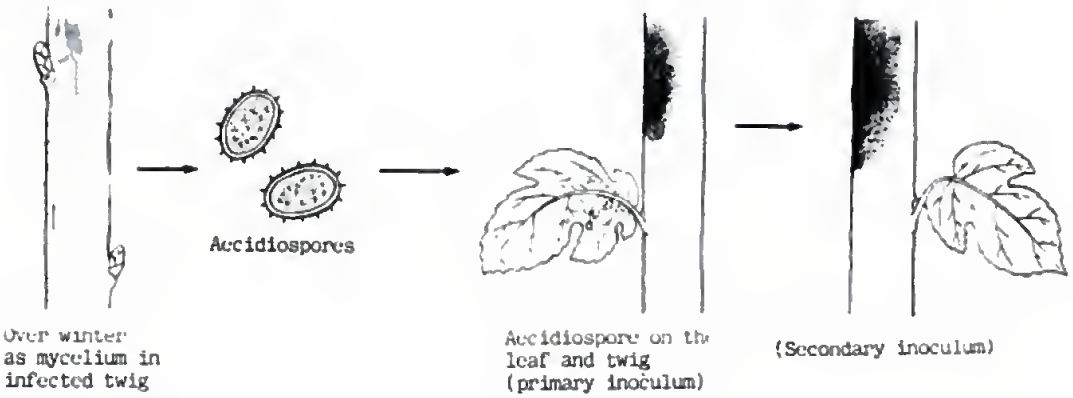


(B)

(b) Favourable conditions:

* Low temperatures (15-20°C) and high humidity
* Continous cloudy conditions
* Dense planting

(c) Disease cycle



(d) Control measures

* Remove infected leaves and new buds
* Remove infected twigs in early spring
* Chemical spray during summer season (Topsin-M 70% WP 1:500, 1 500l/ha)

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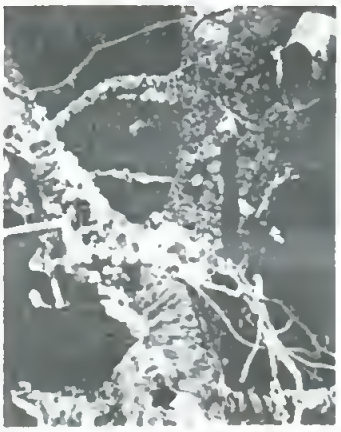
2.1.7 White Root Rot *Rosellinia necatrix* (Hartig) Berlese (*Dematophora necatrix* Hartig)

(a) Symptoms: White velvet-like mycelia spread on stems (A) and roots (B). Within a few years plant withers and dies.

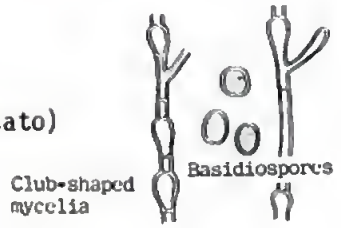
(A)



(B)

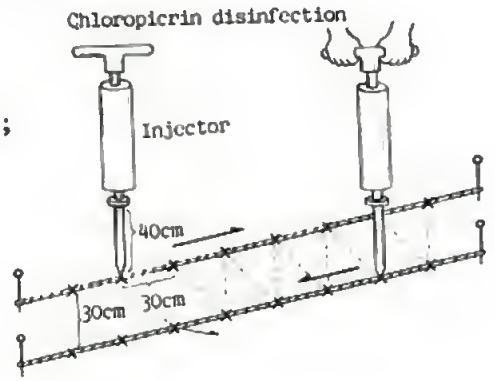
(b) Disease cycle

* Soil-borne pathogen, favourable temperature 15-20°C
* Pathogen typically club-shaped mycelia
* More than 60 hosts (including apple, pear, grape, oak, potato)
* Infection cycle see 2.1.8



(c) Control measures

* Plant infected area with Gramineae at least every four years
* Sapling disinfection: 30 min. with 45°C hot water or 10 min. 0.2% solution Topsin-M 70% WP
* Furrowing: Prepare furrow 40-50cm deep, apply 200-250g PCNB (Pentachloronitrobenzene) 20% D per 1m; plant mulberries 10 days later
* Soil disinfection (see diagram): Prepare Z-shaped furrows and inject 8-10ml chloropicrin per furrow in autumn; cover with polyethylene film for one month and then plough; plant mulberry trees one month later



2.1.8 Violet Root Rot *Helicobasidium mompa* N. Tanaka (*Septobasidium mompa* (Tanaka) Rac)

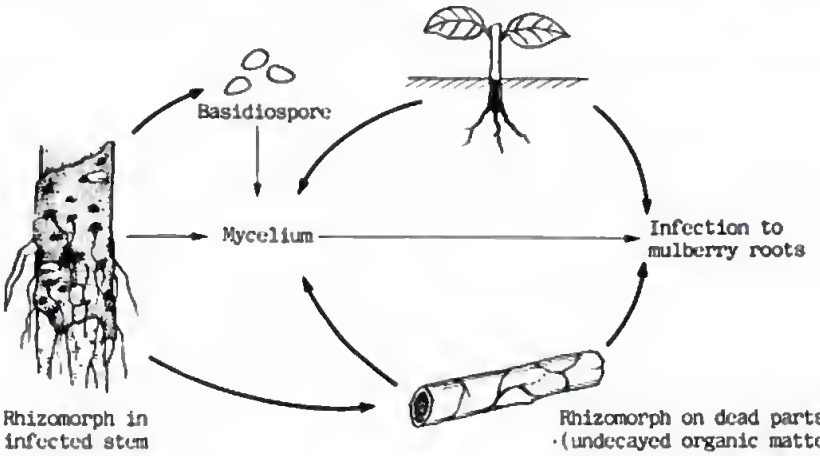
(a) Symptoms: Purple velvet-like mycelia spread on stems and roots. Infected roots rot and thread-like rhizomorphs are visible on roots (A). Infected stems wither within a few years (B).

(A)

(B)

(b) Disease cycle

* Soil-borne pathogen, typically H-shaped mycelia
* Disease usually occurs in new mulberry fields
* Hosts: Apple, pear, peach, willow, pine, potato, bean, peanut, sugar cane, etc.



(c) Control measures

* Plant healthy saplings.
* Cultivate Gramineae crops in infected areas.
* Eliminate infected stems and disinfect soil with chloropicrin (see 2.1.7).
* Sapling disinfection: 30 minutes with 45°C hot water

2.2 PESTS

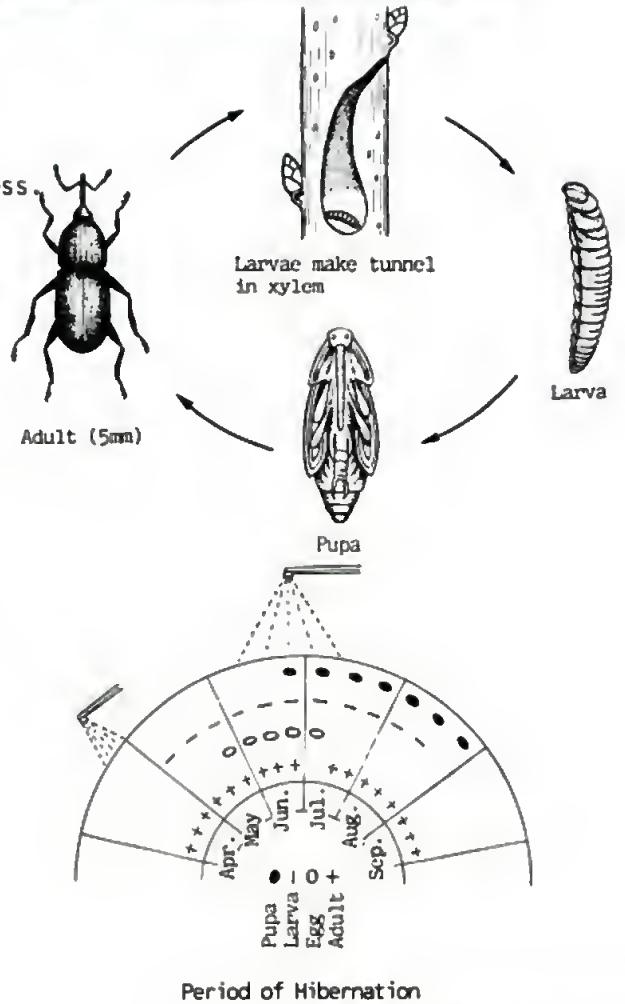
2.2.1 Mulberry Small Weevil *Baris deplanata* Roelofs

(a) Type of injury: Hibernating adults attack winter buds (A), base of young shoots, leaf stalk and buds coming out after spring and summer pruning. The affected buds, leaf stalks and shoots wilt and cannot sprout, so that they deform and die (B).

(A)

(B)

(b) Life history and habits: Usually winters as adult. Female deposits eggs on branch or stalk remaining after pruning. Grubs are white, chunky, legless. Larvae eat out xylem of branch. There is one generation a year. (See diagram of life cycle on right.)

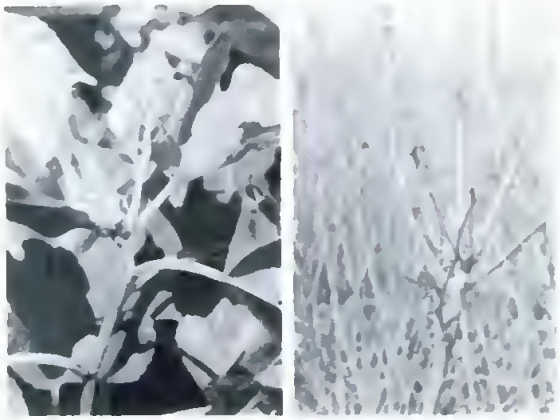


(c) Control measures

* Cut semi-withered branches during winter season
* Chemical spray early spring (Cidial 47.5% EC 1:1 000, 1 300l/ha)
* Chemical dusting after pruning (Thiolix 3% D Diazinon 2% D 40-60kg/ha)

2.2.2 Mulberry Shoot Gall Midge *Diplosis mori* Yokoyama

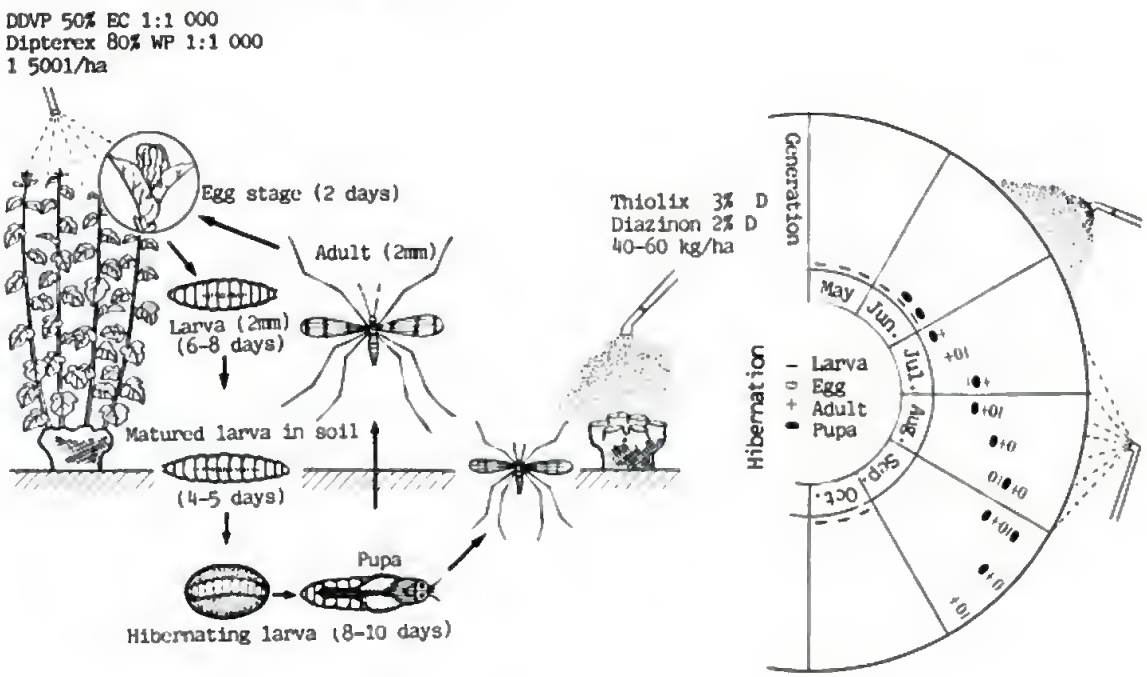
(a) Type of injury: Infested growing parts are distorted, turning brown (A); dying parts have axillary buds sprouting like a broom (B), which in turn have clusters of small leaves. Leaf yield declines and quality of leaves drops. In light infestations the leaves sometimes curl and growth is stunted.



(A) (B)

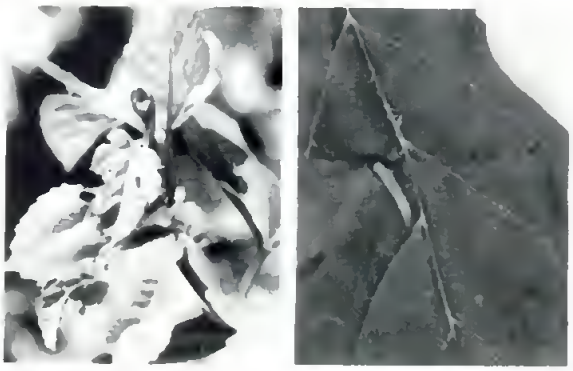
(b) Life history and habits: Larvae winter in cocoons in soil. Adult midges are light orange-red and are usually most abundant in damp fields during summer and early autumn. The females deposit eggs on top of buds, usually just behind speck of buds or on surface of newly-opened leaf. The maggots feed on tender tissue of new growth and inside of buds. There are 4-6 generations a year.

(c) Control measures: Spray chemicals after pruning and during late July and early August (see diagrams below).



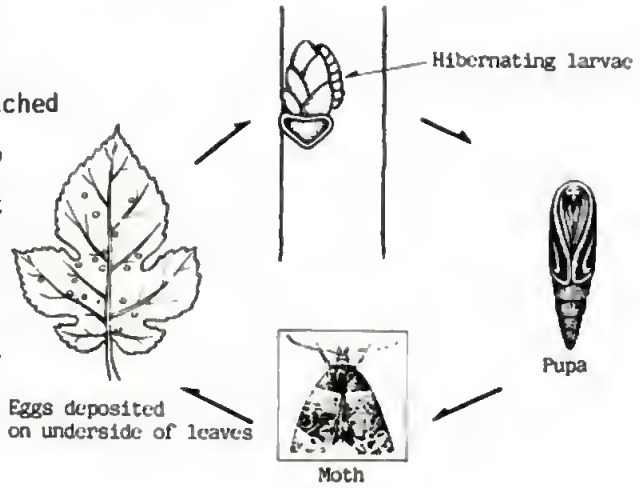
2.2.3 Mulberry Leaf Roller *Olecthreutes hemiplaca Meyrick*

(a) Type of injury: In early spring hibernated larvae attack winter buds, preventing sprouting. Second generation larvae attack terminal buds of young shoots retarding growth in July-August (A), and feed on the underside of the leaves (B).



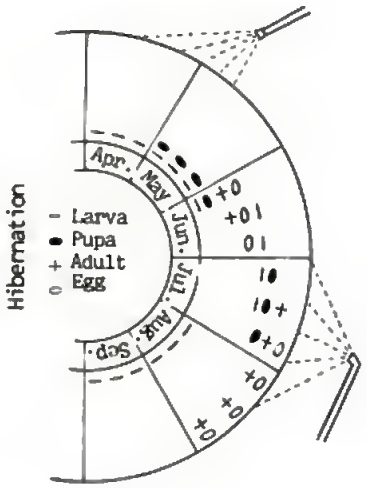
(A) (B)

(b) Life history and habit: Winter as small green worms in silken cases attached to axil of twig, bud, crevice of stump or trash of leaves. The larvae eat out buds and leaves; matured larvae fold edges of leaf attaching their bodies with silk. Female deposits eggs underside of leaf. There are two generations a year.



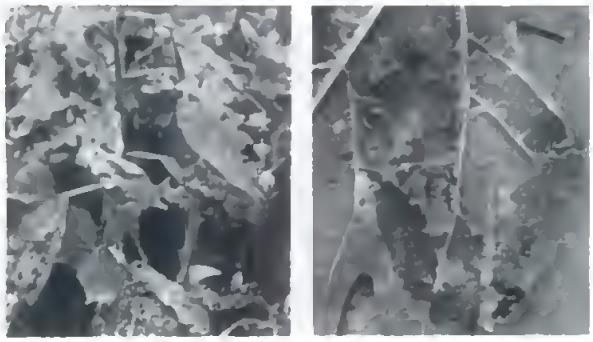
(c) Control measures: Spray chemicals to control hibernating larvae during early spring and July-August (see diagrams below).

Cidial 47.5% EC
DDVP 50% EC
Dipterex 80% WP
1:1 000 1 300-1 500l/ha



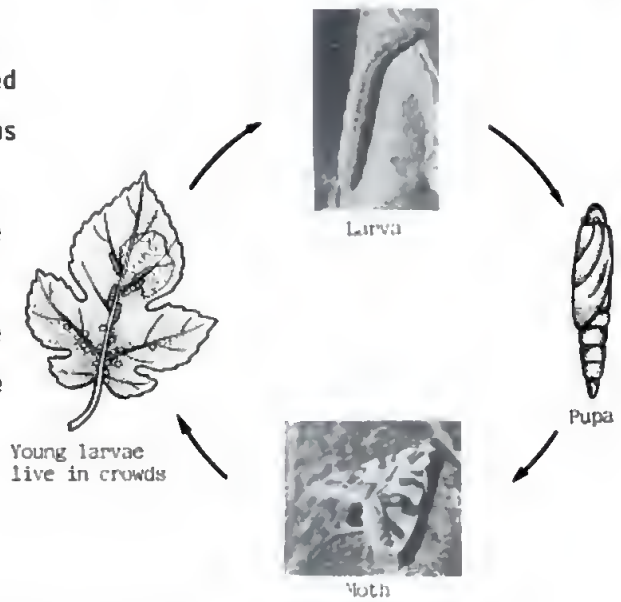
2.2.4 Mulberry Pyralid *Margaronia pyloalis* Walker

(a) Type of injury: Leaves sometimes covered with light web, enclosing two or three leaves or drawing the edges of a single leaf together (A). Under protection of web larvae may consume all the green tissue of the leaf, causing extensive damage in autumn (B).



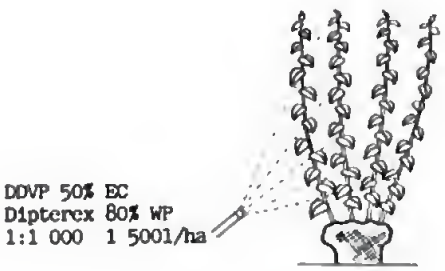
(A) (B)

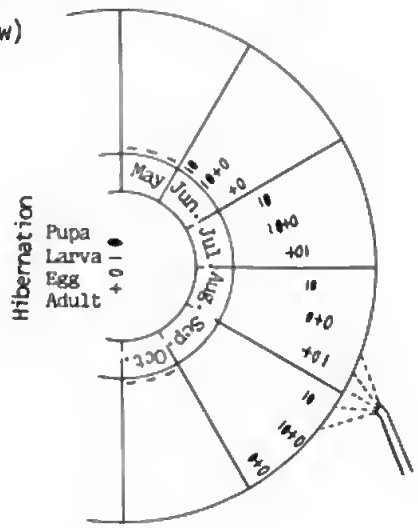
(b) Life history and habits: Winter in larval stage in thin cocoons in withered leaves or crevices of trunk. Adult moths deposit eggs on underside of leaves. Adults inactive during day but assemble around light on warm nights. Young larvae live in crowds but mature larvae scatter and act individually. There are 3-4 generations a year.



(c) Control measures

* Remove fallen leaves and plant refuse during winter
* Spray chemicals early autumn (see diagrams below)



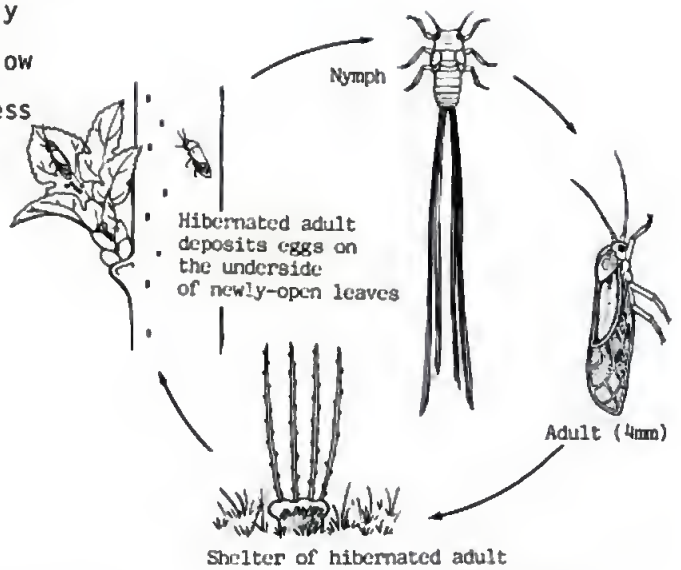


2.2.5 Mulberry Sucker *Anomoneura mori* Schwarz

(a) Type of injury: Hatched nymphs suck sap from newly-opened leaves causing curling and deformation in spring (A). Matured nymphs secrete fine threads of wax late May and early June so that leaves cannot be used for silkworm (B). Wax is toxic to man and skin irritant.

(A) (B)

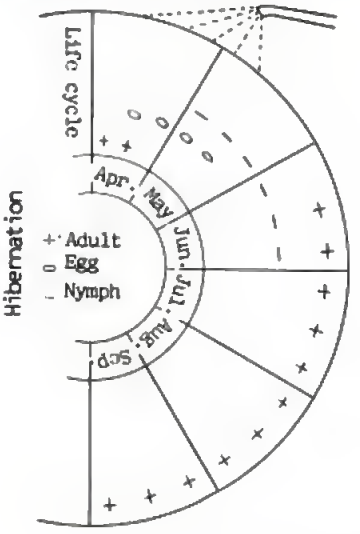
(b) Life history and habits: Hibernated adults come out of hibernation early spring, females deposit orange-yellow eggs on newly-opened leaves. Wingless nymphs live on underside of leaves, sucking sap and secreting 3-4 bundles of white wax composed of fine threads. Adults live on mulberry leaves till they fall then fly to weeds. There is one generation a year.



(c) Control measures

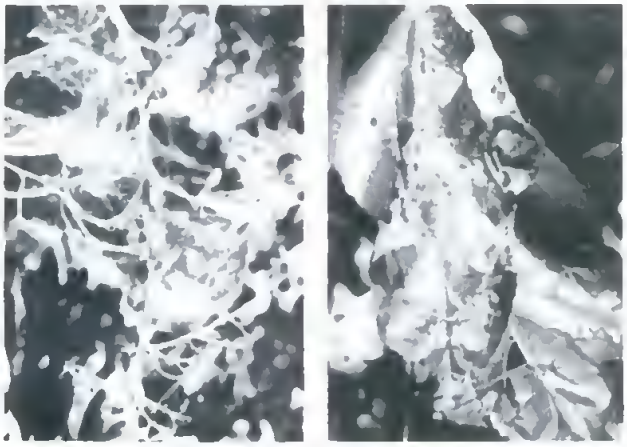
* Remove deformed leaves containing nymphs
* Spray chemicals when buds sprout and mid-May

DDVP 50% EC
Dipterex 80% WP
1:1 000
1 300-1 500 l/ha



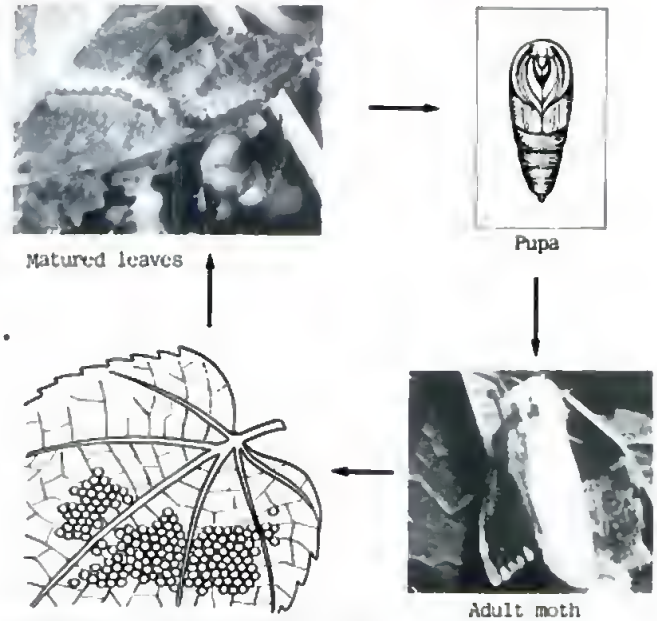
2.2.6 Fall Webworm *Hyphantria cunea* Drury

(a) Type of injury: Presence indicated by loosely-woven dirty white web enclosing foliage on ends of branches, sometimes covering several branches (A). The webs enclose many caterpillars, 2-3cm long, which feed on the leaves (B). Hosts include more than 100 shade, fruit and woodland trees.



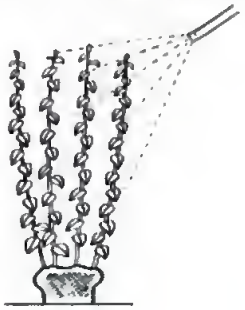
(A) (B)

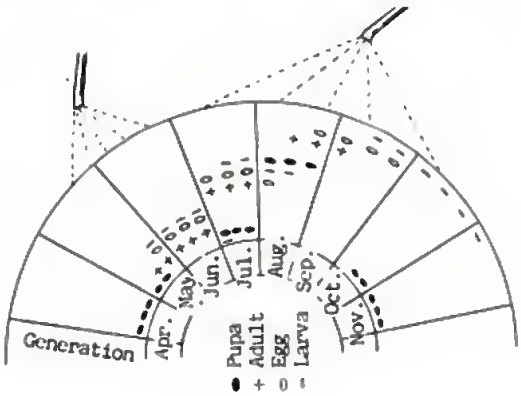
(b) Life history and habits: Winter in pupal stage, enclosed in lightly-woven silken cocoons found under rubbish on the ground or under bark of trees. Although 1st to 3rd instar larvae live in crowds in webs, 4th instars scatter and act individually. Larvae devour all leaf except for veins. About three life cycles completed a year.



(c) Control measures

* Remove web-enclosed larvae
* Spray chemicals (see diagrams)





2.2.7 Mulberry Yellow Tail Moth Porthesia xanthocampa Dyer

(a) Type of injury: Hairy caterpillars strip the mulberry leaves (A). The caterpillars can cause irritation to humans, even serious illness, because of their nettling hairs.

(A)

(b) Life history and habits: Winter in larval stage in thin cocoons in withered leaves or crevices in branches. Larvae have bright red tubercles with tufts of long black hairs and nettling hairs. Female moth deposits about 500 eggs on a twig or the underside of a leaf. There are three generations a year.

(c) Control measures

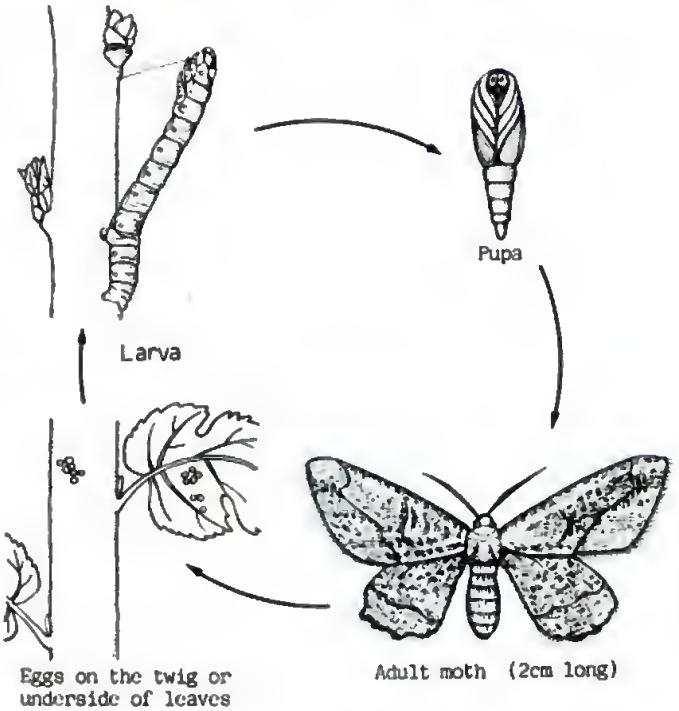
* Remove egg masses
* Spray chemicals early spring and after summer pruning

2.2.8 Mulberry Looper Homerophila atrilineata Butler

(a) Type of injury: Hibernated larvae feed on winter buds, newly-opened leaves and young shoots in spring, skeletonizing the tree (A).

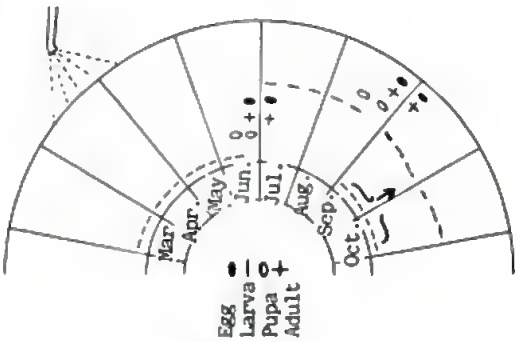
(A)

(b) Life history and habits: Winters as 3rd instar larvae in withered leaves. Larvae stand erect and rigid on hind legs with body projecting outwards from the branch during the day and feed on the leaves at night. Female moth lays 800-1 000 eggs on underside of leaves or twig in masses of 30-40. There are two generations a year.



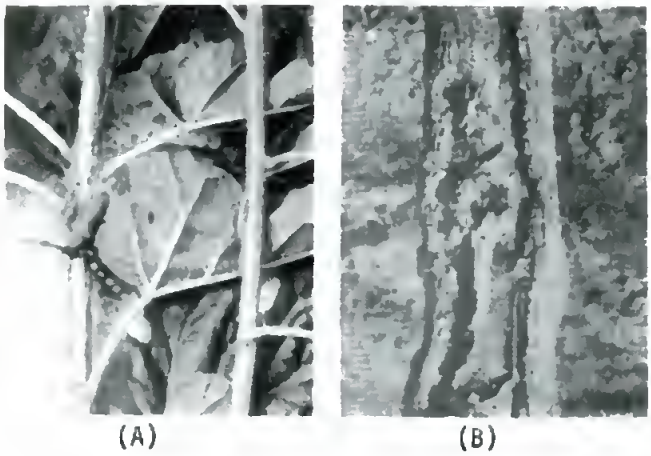
(c) Control measures

* Remove larvae
* Spray chemicals April-May
  (DDVP 50% EC Dipterex 80% WP
  1:1 000, 1 300-1 500l/ha)

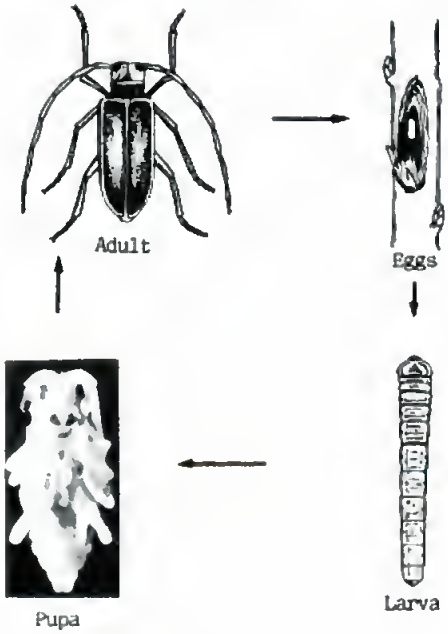


2.2.9 Mulberry Borer *Apriona japonica* Thomson

(a) Type of injury: The imago bites the epidermis of one-year-old branch and the female deposits eggs in long thin groove (A). Infested trees have many large burrows showing through the bark on the trunk and large branches (B). Infested trees will gradually weaken, branches or trunk will break during high winds.

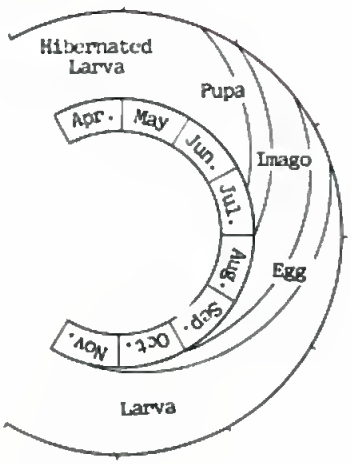


(b) Life history and habits: Winter in larval stage. Larvae creamy yellow with brown heads and a rounded thickening behind head. Hatched larvae eat sapwood and invade centre of trunk; early spring pupate and emerge as fully grown insects June-July. Imago is about 5cm long, blackish-brown and covered with minute greyish-yellow hair. The insect requires two years to complete life cycle.



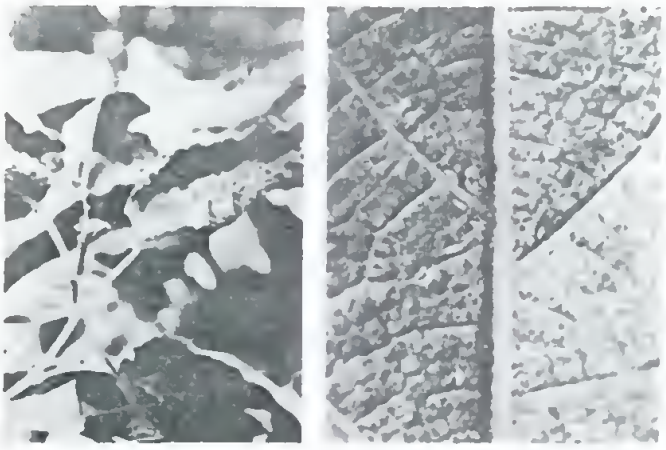
(c) Control measures

* Use flexible wire to kill larvae deep in wood
* Kill larvae by injection of solution of organophosphorus insecticide into the burrows (i.e. D.D.V.P., etc.)
* Collect and kill imagos



2.2.10 Mulberry Thrip *Pseudodendrothrip mori* Niwa

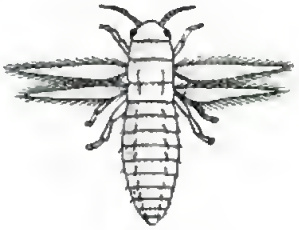
(a) Type of injury: Upper leaves of branch becomes blasted and deformed; later leaves may wither, curl up (A) and become spotted with small brown spots (B). Where symptoms numerous leaf appearance is marred and they are usually unsuitable for silkworms.



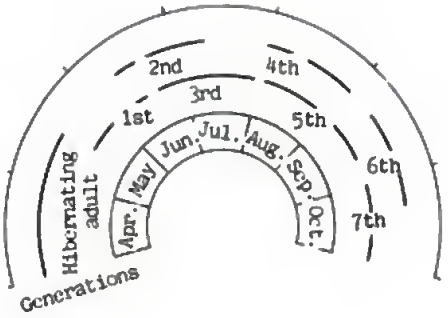
(A) (B)

(b) Life history and habits: Adult winters on branches or in rubbish in fields or weeds. Female deposits eggs in slits in leaves; nymphs (A) and adults (B) feed on leaf tissue, rasping the leaf and sucking the sap flowing from the injured area. There are usually 7-8 generations a year.

(A)

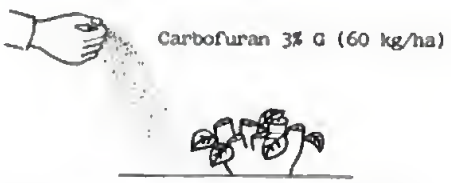


(B)



(c) Control measures

* Spray chemical before silkworm rearing



* Spray with Metasystox and Ortran when thrips appear on foliage. (25% EC, 1:1 000, 1 300 - 1 500 l/ha)

2.2.11 Mites

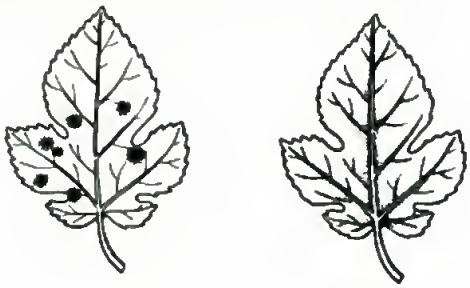
Two Spotted Spider Mite *Tetranychus telarius* Unnaeus

Citrus Red Mite *Panonychus citri* McGregor

Suginami Spider Mite *Eotetranychus suginamiensis* Yokoyaha

(a) Type of injury: In hot dry summer-autumn mulberry leaves become blotched with pale yellow and reddish-brown (A) on both upper and lower surfaces. Severely affected leaves have pale sickly appearance (B) and gradually die and drop (C). Undersides look as though they have been dusted with fine white powder.

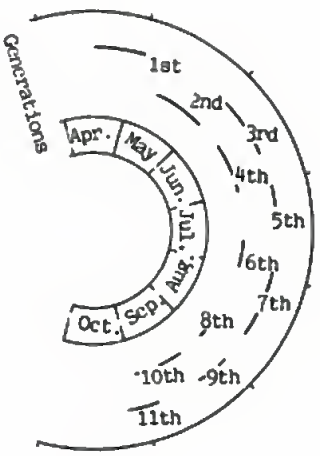
(C)



(A) (B)

(b) Life history and habits: Female imago is elliposidal (A) and male has a narrow body with a pointed abdomen (B). Citrus red mite and two spotted spider mite hibernate in egg and adult stages respectively. Generally entire life cycle requires 3-5 weeks depending on temperature and there may be as many as ten generations a year.

(A) (B)



(c) Control measures

* Spray acricides

Kelthane 42% EC
Tedion 8% EC
1:1 000 1 300-1 500l/ha

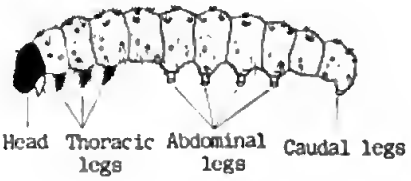
Chapter 3: SILKWORM REARING

3.1 INTRODUCTION

3.1.1 Description of Silkworm: Sericulture is concerned with the Bombyx mori or mulberry tree silkworm. The various features of the silkworm at different stages of development are examined below.

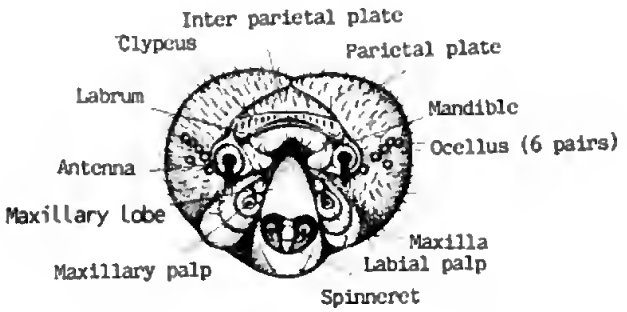
(a) Newly-born worm ('ant worm')

The newly-hatched worm had 13 segments and resembles tiny black ants at a glance because of dense black bristles on the body, thus called ant worms.

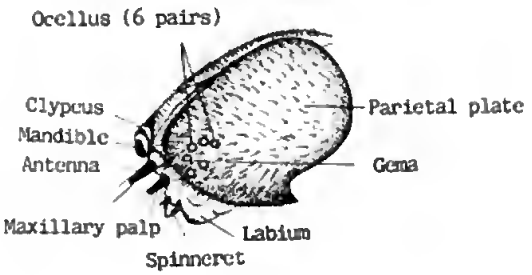


(b) Front view of larval head

Six pairs of ocelli are located at the base of the antenna to sense lightness. Around the mouth, there are two antennae to smell, maxilly palp to taste and a spinneret to spin silk filament.

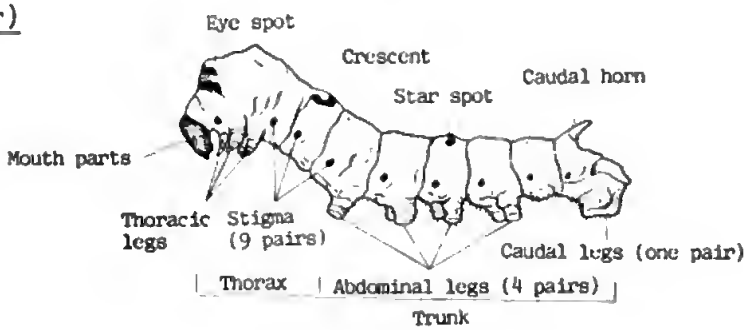


(c) Side view of larval head: The six pairs of ocelli are situated at the base of the antennae and sense the light density (but do not identify image). One pair of mandibles serves to bite the mulberry leaves.



(d) Adult larva (5th instar)

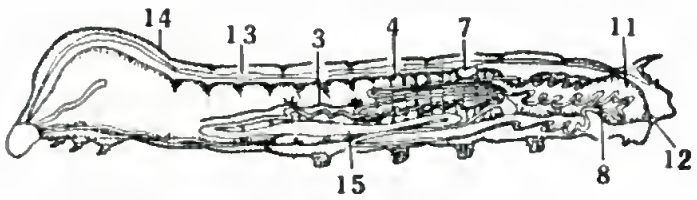
Atthe peak of its growth, after feeding on mulberry leaves for 23-25 days, the larva weights 506 grams, ten thousnad times the weight of newly-hatched larvae.



- Integument and main internal organs in the silkworm

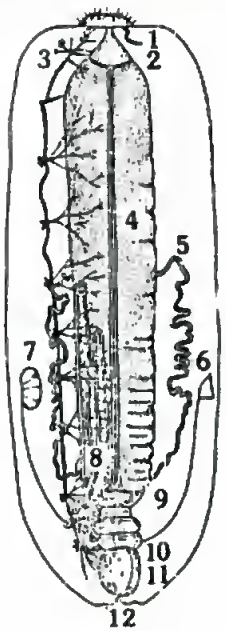
The silkworm has an integument, also termed exo-skeleton. A part of this endo-skeleton is found in its vertebrate; this supports and protects the internal organs, due to its rigidity. The internal organs of the silkworm are the following: an alimentary canal, a silk gland, Malpigian tubes for excretion purposes and a dorsal, longitudinal vessel comprised of a posterior heart and interior aorta spiracles, nervous system and reproductive organs.

Alimentary canal



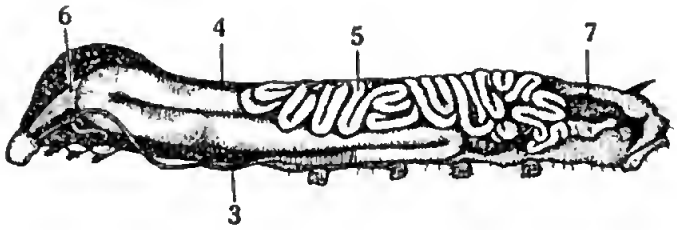
The alimentary canal is comprised of three regions: foregut, middlegut and hindgut. The midgut, primarily concerned with the production of enzymes and absorption of digestion products, occupies the largest area of the canal. It consists of a muscular layer, basement membrane, epithelian cell layer and peritrophic membrane. Only the latter is renewed at each ecdysis. The hindgut is comprised of three regions: intestine, colon and rectum and is renewed also at ecdysis, together with the foregut. The alimentary canal gradually degenerates during larval-pupal transformation.

1. Salivary gland
2. Oesophagus
3. Trachea
4. Mid-intestine
5. Silk-gland
6. Ovary
7. Testis
8. Malpigian tube
9. Small intestine
10. Colon
11. Rectum
12. Anus
13. Dorsal vessel
14. Skin
15. Silk-gland

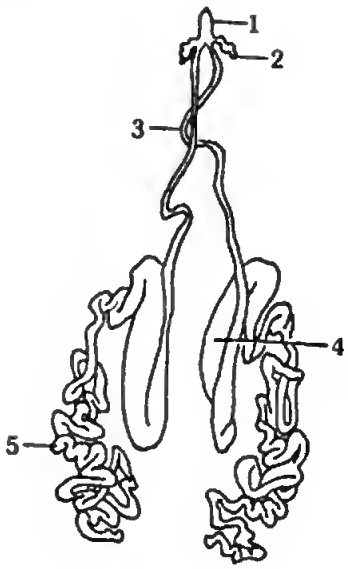


Silk-gland

The growth rate of the silk-gland is very high during larval development. The silkworm increases the weight of its silk-gland up to 160 000 times during the developmental period from the newly hatched larvae to the matured larvae. In particular, the weight of the gland occupies about 5 percent of the total body weight in the newly ecdysed 5th instar larvae. In the mature larvae it occupies a portion of 40 - 50 percent of the body weight. The silk-gland is divided into three parts, according to their secretory function: anterior, middle and posterior division. The posterior silk gland synthesizes exclusively silk fibroin. In the middle silk gland, sericin, another silk protein is secreted into the gland lumen. The anterior silk-gland is a narrow duct and is important in the process of spinning silk protein.

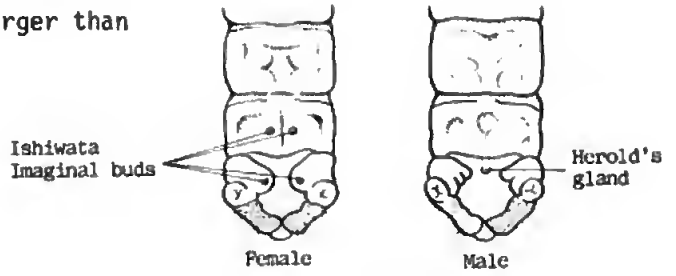


1. Spinnert
2. FILIPPI's gland
3. Anterior division (region)
4. Middle division (region)
5. Posterior division (region)
6. Oesophagus
7. Rectum



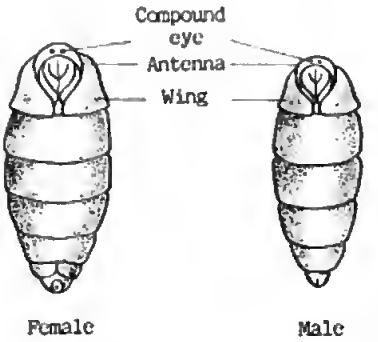
(e) Sexual features: Female silkworm larvae, pupae and moths are larger than the male.

A pair of round milky spots are located on each abdominal side, 11th and 12th segment in females. There is a milky spot on the border of the 11th and 12 segment in males.



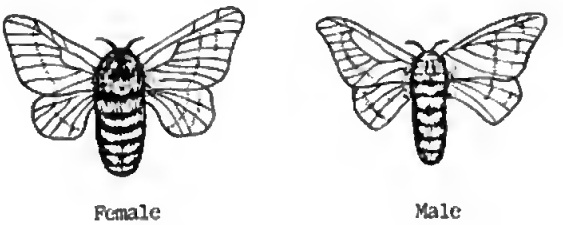
(f) Pupal stage

Female pupae can be distinguished from males by the "x" shaped groves at the abdominal centre of the 8th segment.



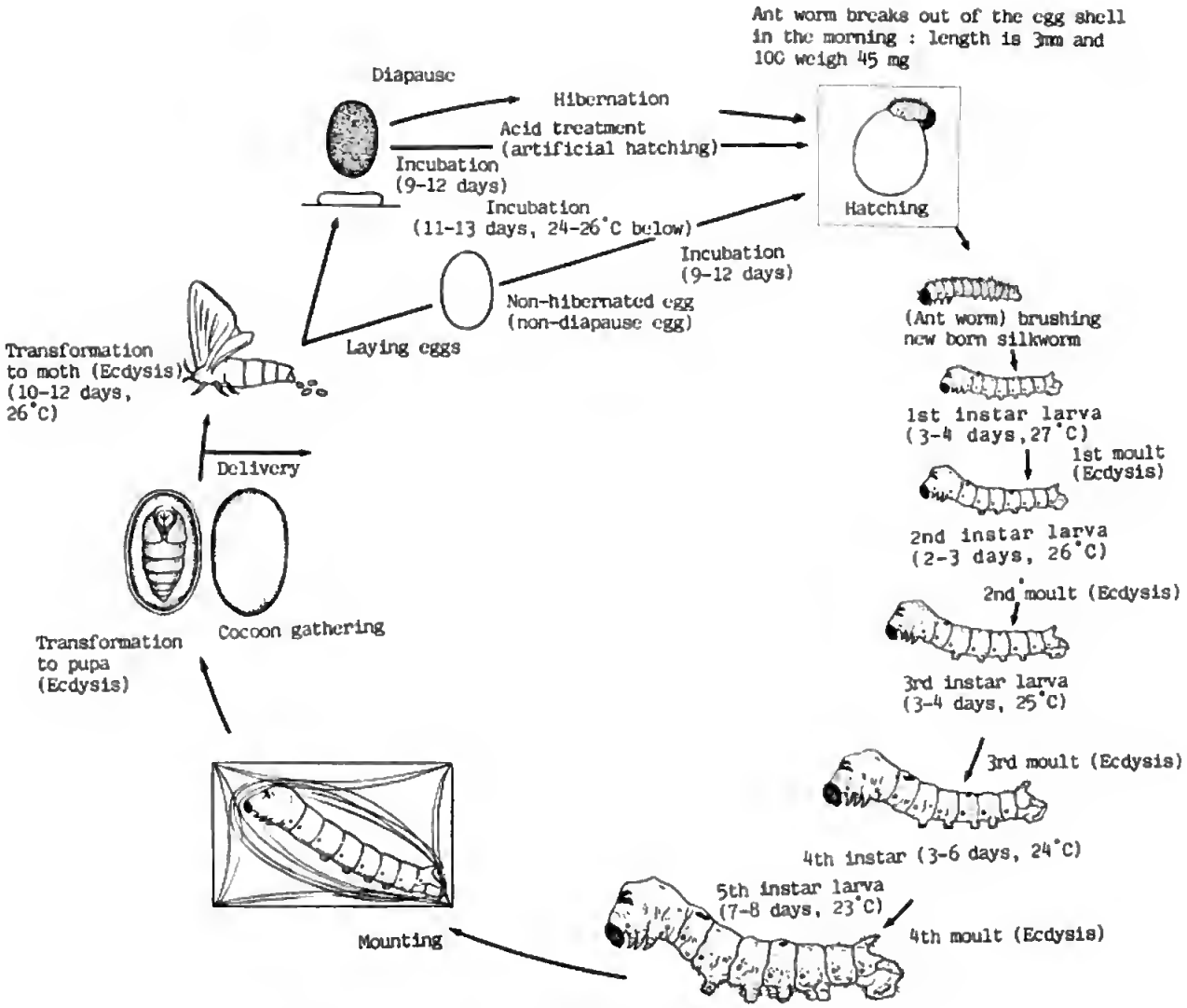
(g) Moth stage

A pair each of prominent antennae and compound eyes are on the heads of moths. There are 3 pairs of thoracic legs and two pairs of wings on the thorax. Moths can not fly, but the males are more active in movement than females.



3.1.2 Life Cycle of Silkworm: The silkworm egg hibernated during winter will hatch in spring when the mulberry sprouts. It goes through 4 moults before reaching maturity and takes 48-72 hours to spin its cocoon. In 2-3 days it transforms into a pupa and after another 10 days emerges as a moth. Emergence takes place in the morning when copulation also occurs. The female lays eggs from evening to next morning and dies within 4-5 days after emergence. The moth lays 500-700 eggs (100 eggs weigh about 60mg). Under the natural cycle the silkworm which produces one generation a year is called univoltine, bivoltine if there are two and multivoltine if there are more. In tropical zones the common variety is multivoltine: under favourable rearing conditions the larvae are very resistant but they produce small cocoons and consequently the quality of the silk is lower than the temperate varieties which are usually uni- or bi-voltine.

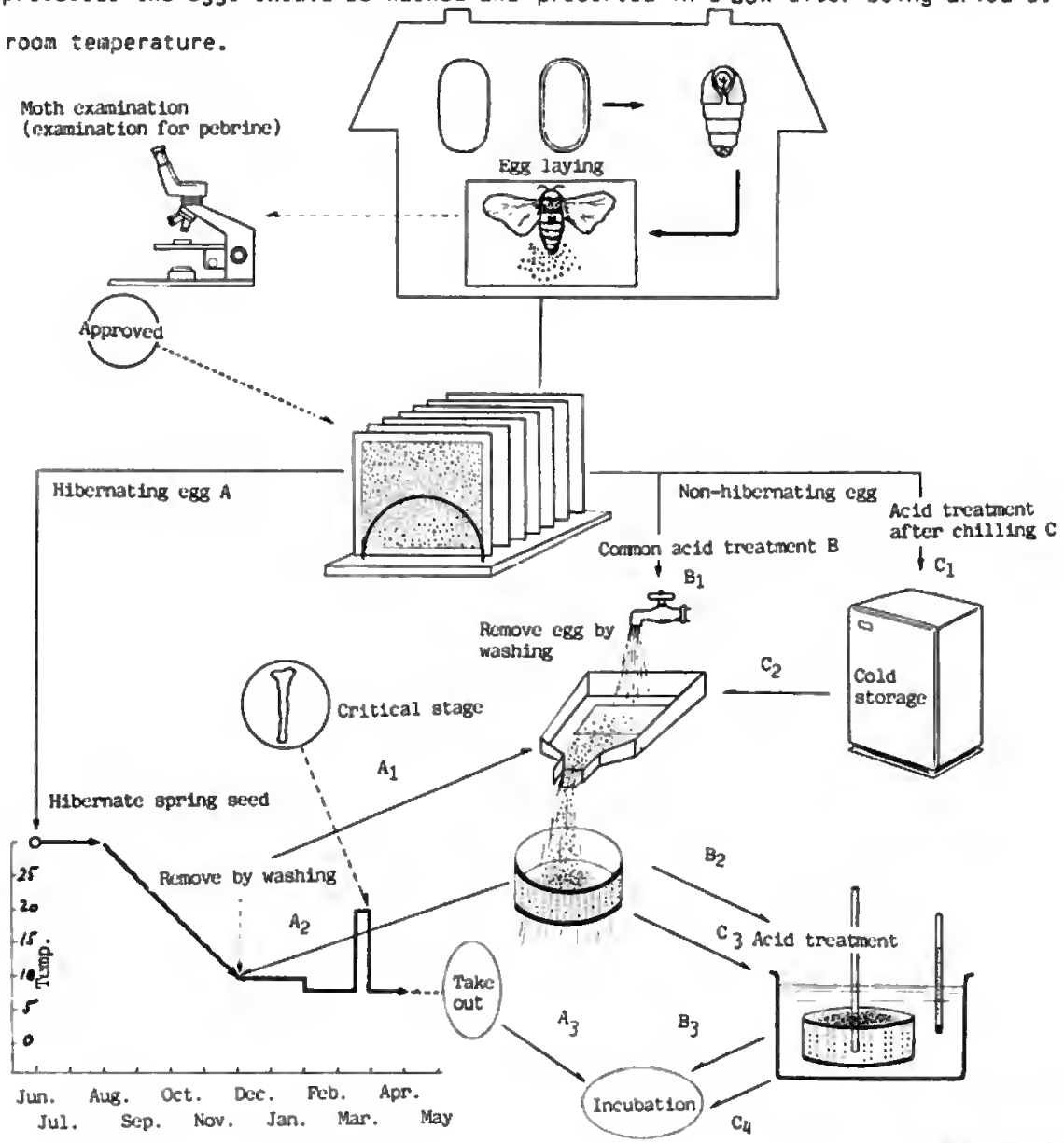
Incubation 13-14 days (15°C, 3 days after 24-25-26°C)		
	Silkworm body	Silkworm glands
1st	20	30
2nd	120	70
3rd	730	220
4th	2640	1800
5th	10 000	140 000



Spinning of cocoon takes 2-3 days.
Evaporation of moisture has to be controlled as it affects reeling - spinning of the cocoon takes 3 days
length of filament 1 200 - 1 600 m and diameter 0.002 m

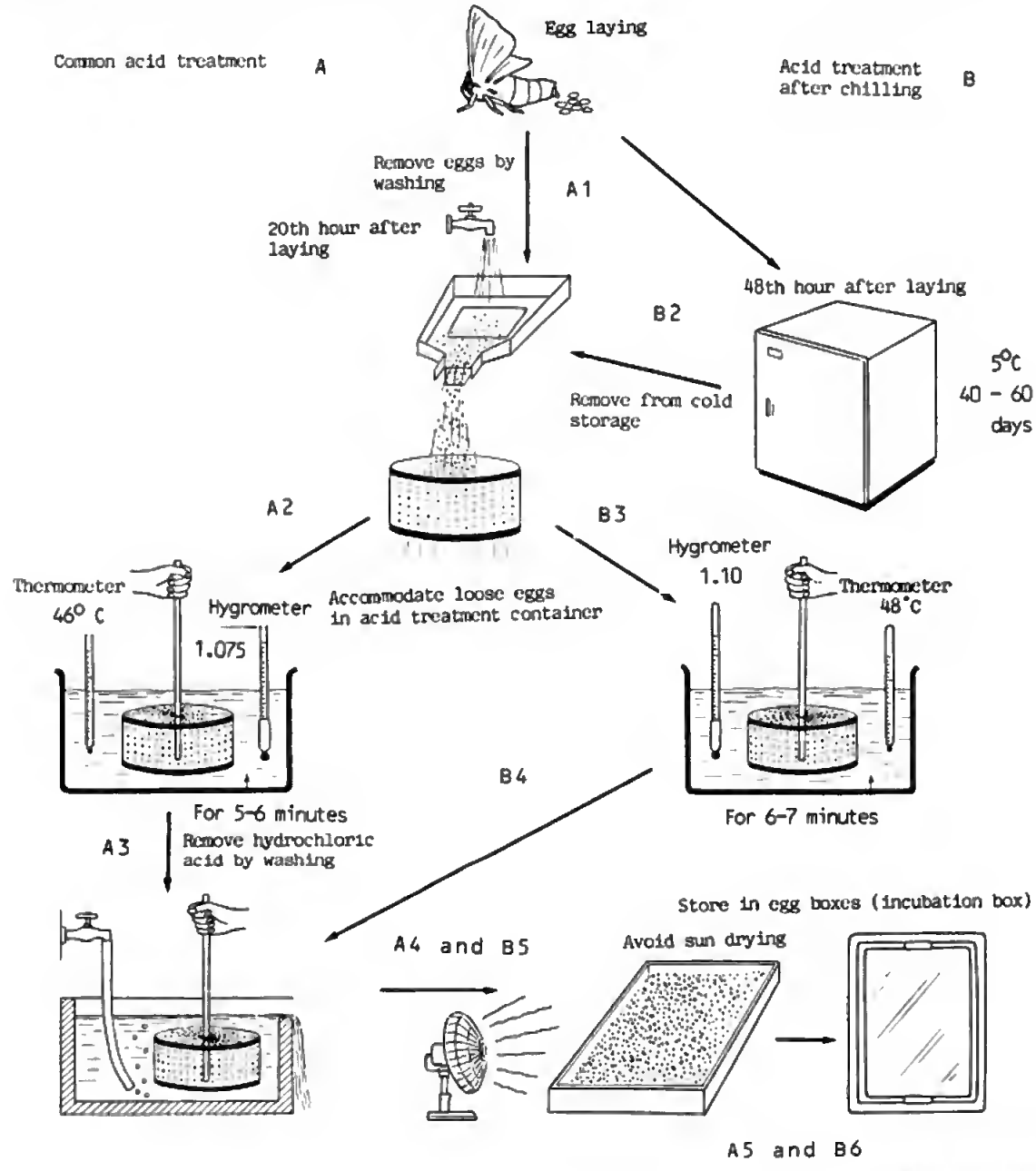
3.2 EGG DEVELOPMENT

3.2.1 Silkworm Egg Production: After the eggs have been checked for pebrine disease they may be treated in one of three ways depending on when hatching is required. Process A (see diagram below) allows the egg to take its natural course. The temperature graph below shows requirements for embryo development under natural conditions in temperate zones (e.g. China, Japan, Korea). In process B the diapause is broken by an acid treatment to start the early development of the embryo (see 3.2.2). Under process C the diapause is halted for periods of up to two months; when incubation is required process B is activated. In all three processes the eggs should be washed and preserved in a box after being dried at room temperature.

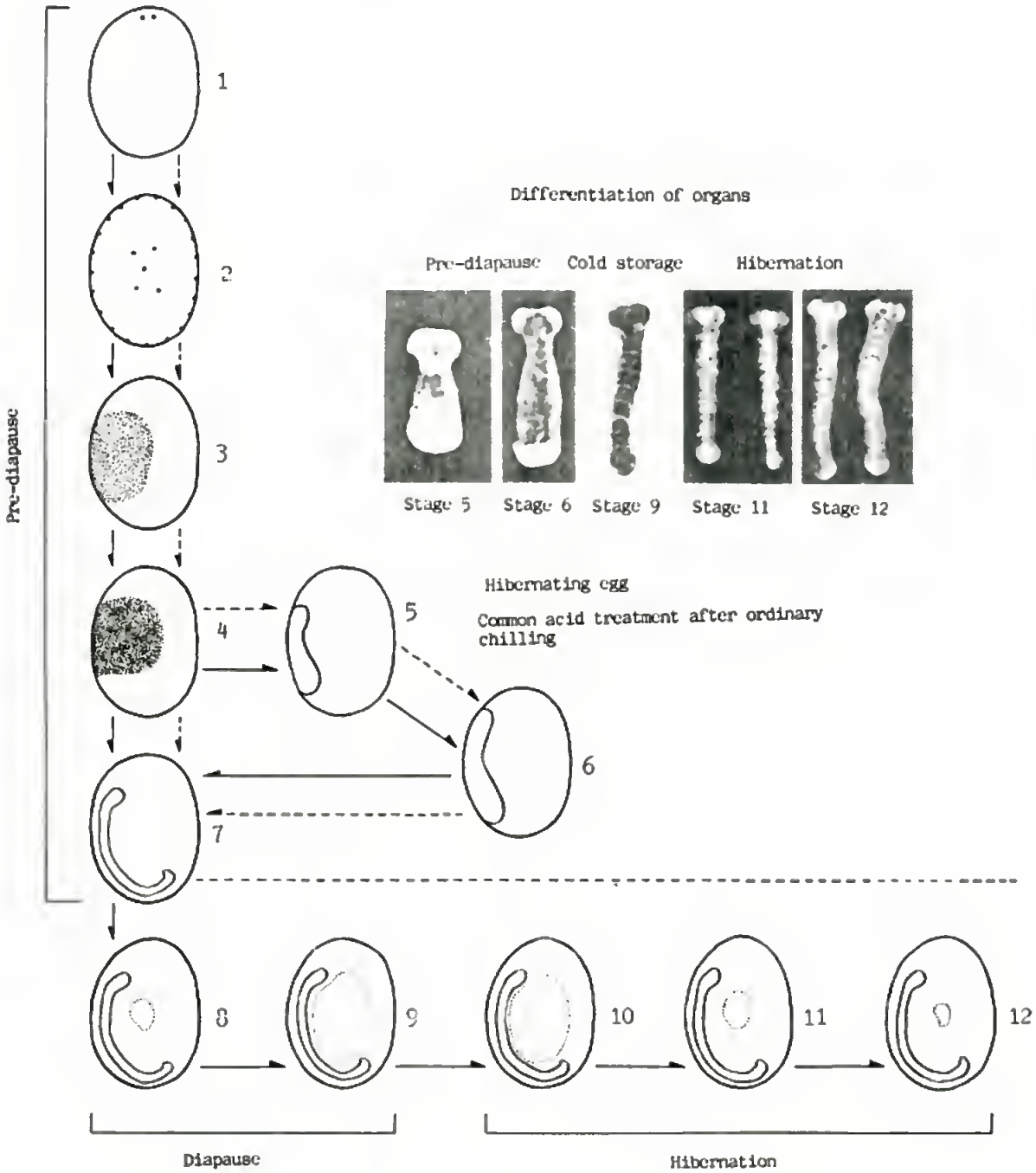


3.2.2 Artificial Hatching of Silkworm Eggs: Eggs stored under natural conditions will not hatch until the spring following laying. If eggs are to be hatched in the same year, artificial methods will have to be used. The following table shows brushing period and cold storage duration for the various acid treatment processes and the diagram follows the procedures step by step.

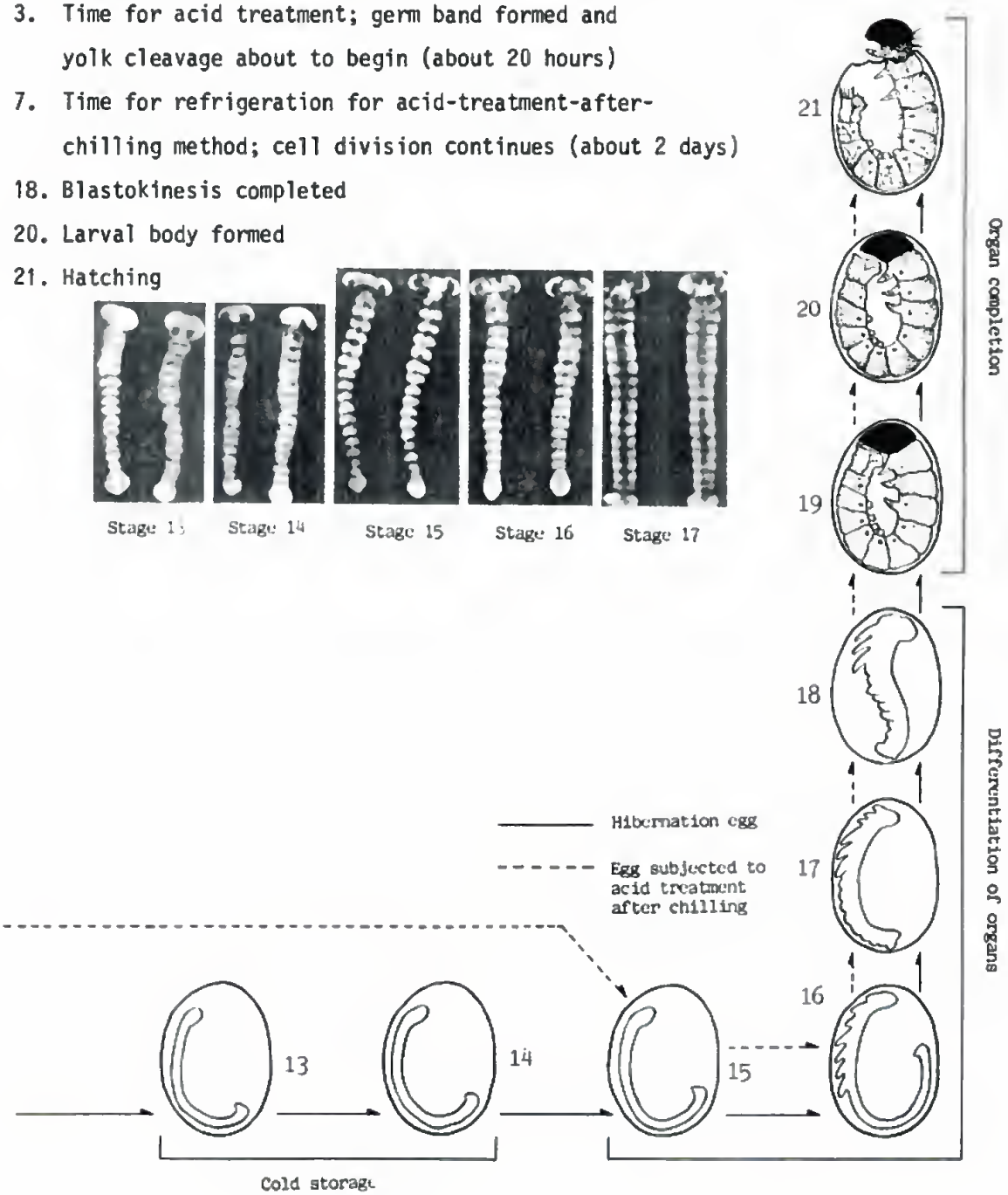
Treatments	From egg laying to brushing	Cold storage duration
Common acid treatment	Within 30 days	20 days
Acid treatment after short-term chilling	30-50 days	24-35 days
Common acid treatment after ordinary chilling	50-75 days	40-60 days



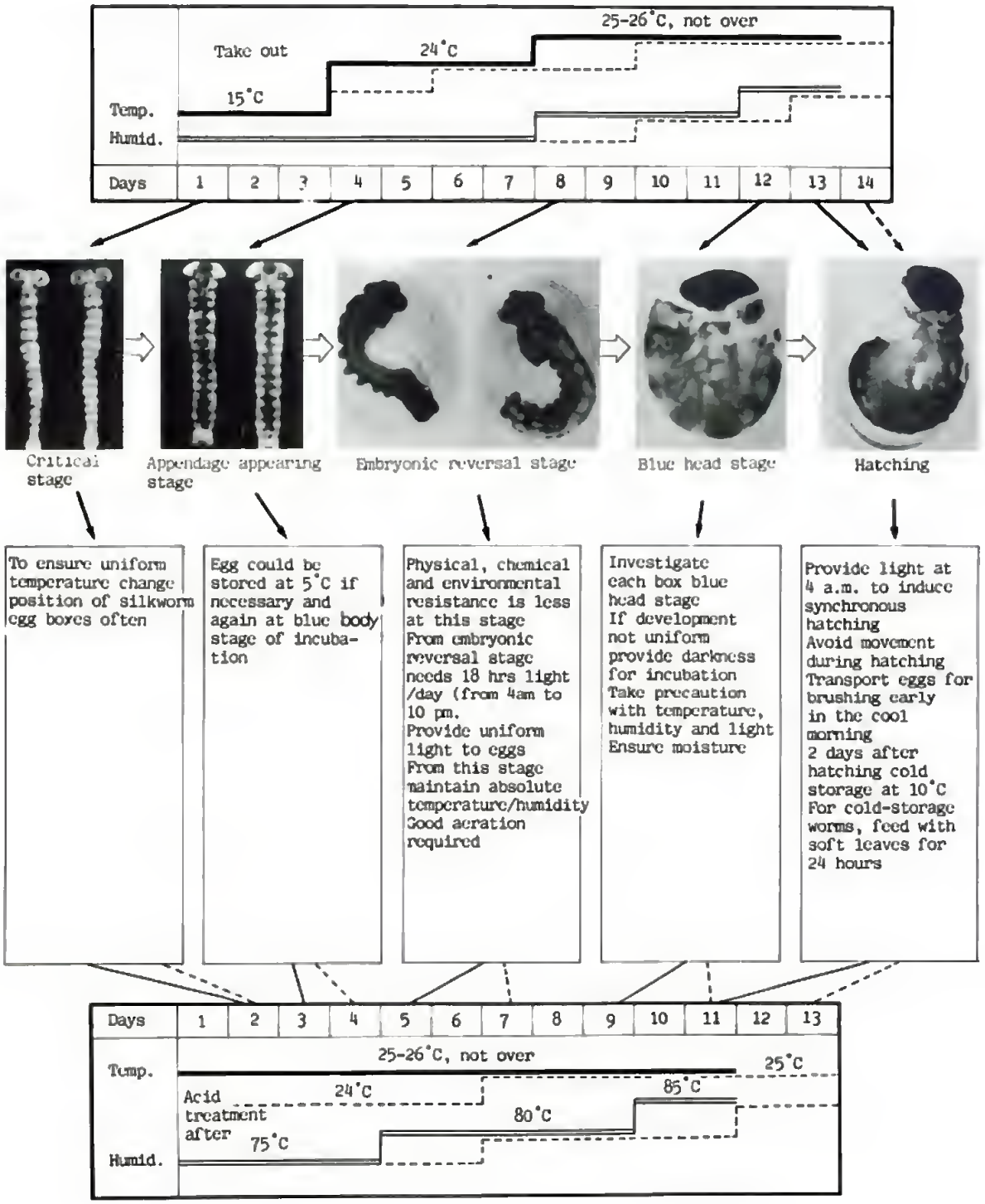
3.2.3 Development of Silkworm Embryo: Cell division takes place soon after fertilization. When the development of the embryo is completed the worm breaks the shell and comes out of the egg. The newly-born larva is black and grey and covered with hairs -- also called 'ant worm' or 'hairy worm'. The following diagram follows this development through each stage.



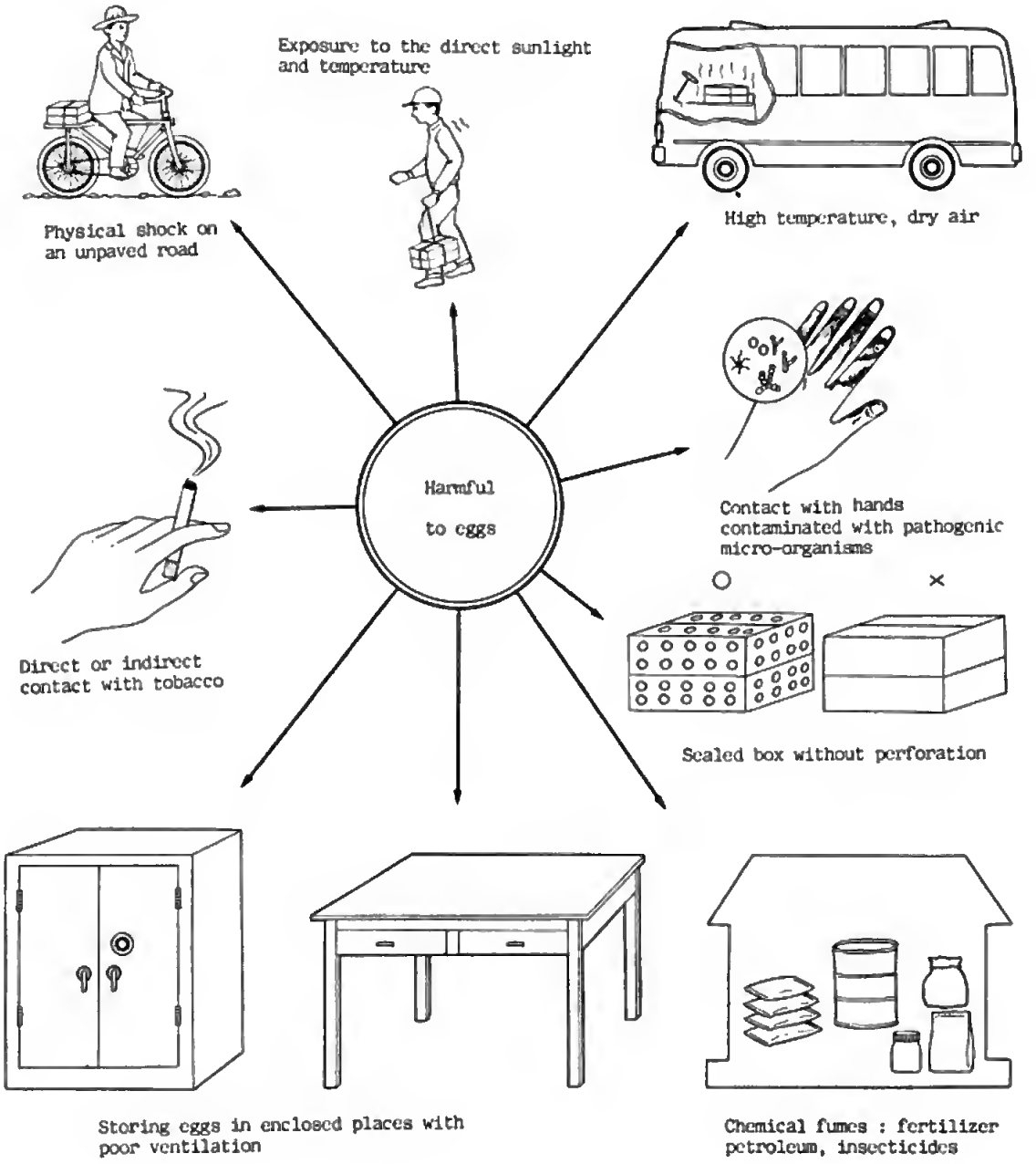
1. Sperm enters egg during oviposition
2. Cleavage nuclei on surface of egg (about 10 hours)
3. Time for acid treatment; germ band formed and yolk cleavage about to begin (about 20 hours)
7. Time for refrigeration for acid-treatment-after-chilling method; cell division continues (about 2 days)
18. Blastokinesis completed
20. Larval body formed
21. Hatching



3.2.4 Incubation: Conditions of incubation affect hatchability and vitality of worms and ultimately the cocoon crop. The following diagram shows the temperature/ humidity requirements at various stages of development.

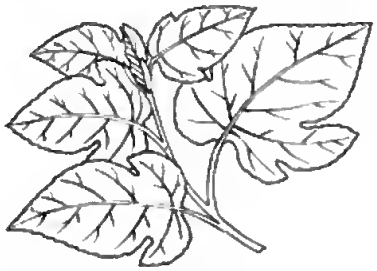


3.2.5 Handling of Silkworm Eggs: Eggs are silkworm seeds in which active development of embryo is in progress. After incubation of the eggs they will have to be delivered to the farmers for rearing and unless care is taken in handling them harmful effects may result. The diagram below shows the most common potential dangers.

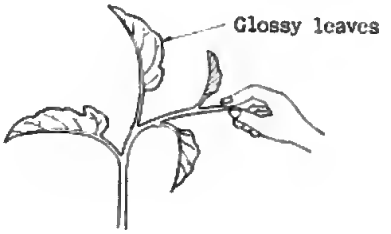


3.2.6 Brushing: After hatching the eggs must be separated from their shells. The most common method is brushing which involves placing mulberry leaves on special frames to attract the larvae and thereby separate them from their shells.

(a) Mulberry leaves for brushing: The most appropriate leaves to use in this process are the first five leaves on the spring shoot (A) or the two uppermost glossy leaves in summer and autumn (B).



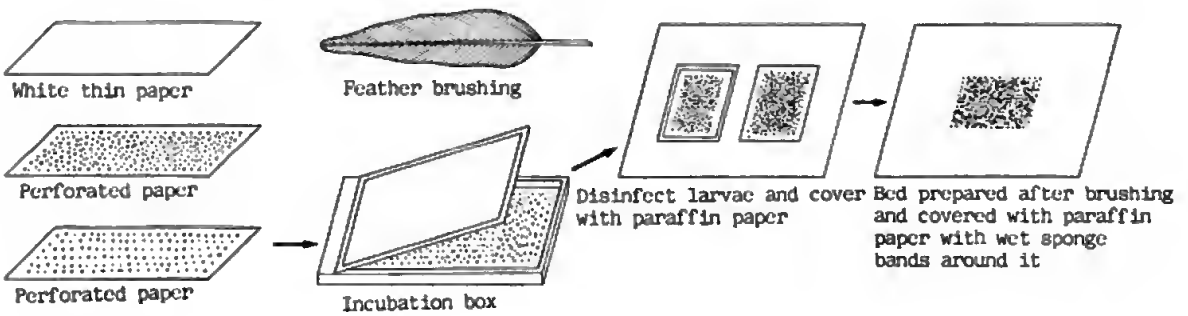
(A)



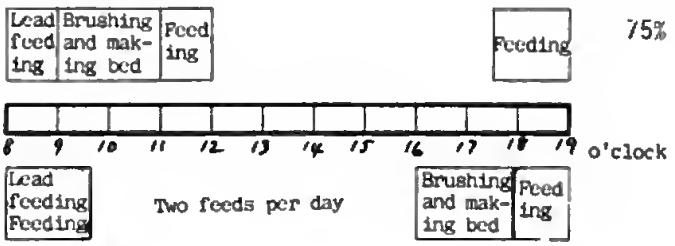
(B)

(b) Conditions: The optimum time for brushing is around 10 a.m. Humidity should be maintained at 85-90% and temperature at 27°C during the process.

(c) Methods:



(d) Labour-saving brushing: To reduce labour demands the following regime may be followed.

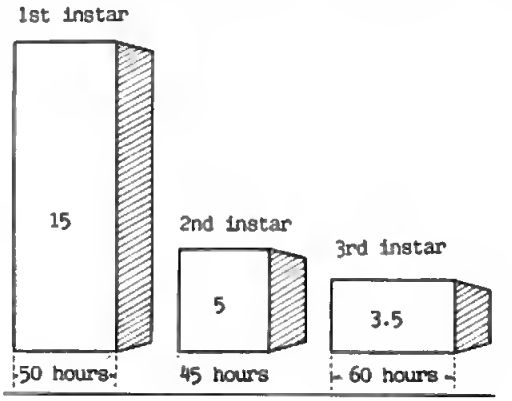


(e) Delayed brushing method: If hatching is poor temperature should be reduced to 22°C and humidity to 75% to promote greater uniformity.

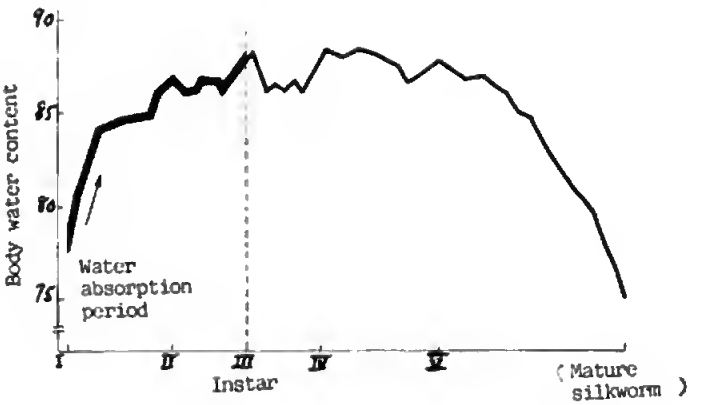
3.3 REARING OF YOUNG SILKWORMS

3.3.1 Characteristics and Demands of Young Silkworms: Young and adult silkworms behave differently during rearing and require different techniques for each instar particularly in relation to leaf quality and environmental conditions. Early stage silkworms need closer care and attention as their resistance to disease is low.

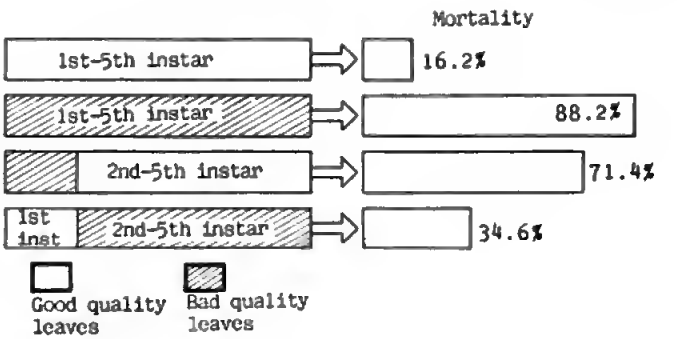
(a) Growth ratio: Diagram shows relative growth rate at the first three instar stages. The growth rate of the 1st instar is very fast and if nutrition is poor growth may be retarded.



(b) Water content: In newly-born larvae water content is very low but increases rapidly up to 2nd instar when fed mulberry leaves. It requires high water content in leaves at this initial stage.



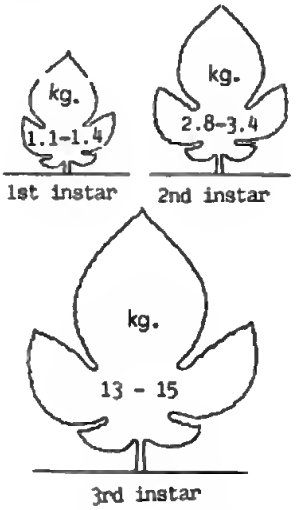
(c) Leaf quality: The importance of high quality leaves for 1st and 2nd instar larvae is demonstrated in this diagram.



(d) Eating/digestion ratio: At the initial stages ingestion is low but digestion is high.

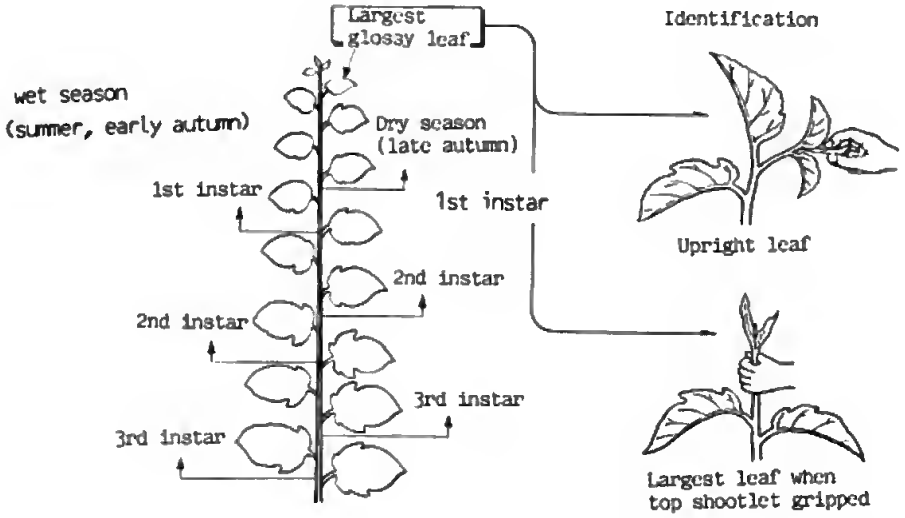
3.3.2 Leaf Feeding: Both quantities of leaf fed and actual leaf quality requirements are different for each stage of larval development.

(a) Quantity: The adjoining diagram shows the relative leaf weight requirements (kg/box) for 1st to 3rd instar larvae.

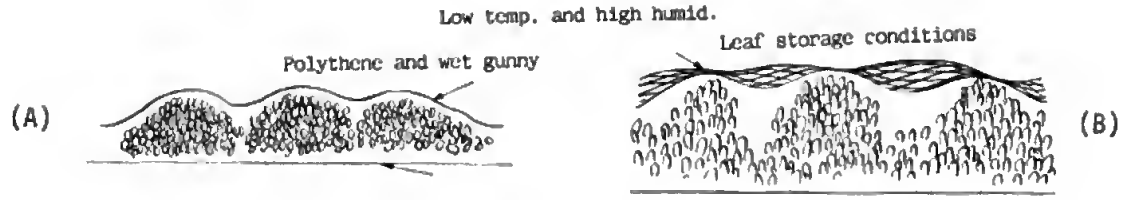


The feeding amount increases abruptly from the 3rd instar larvae. The excess amount of leaves should be given to slow down drying of leaves and to present an opportunity for worms to choose the right leaves to feed on.

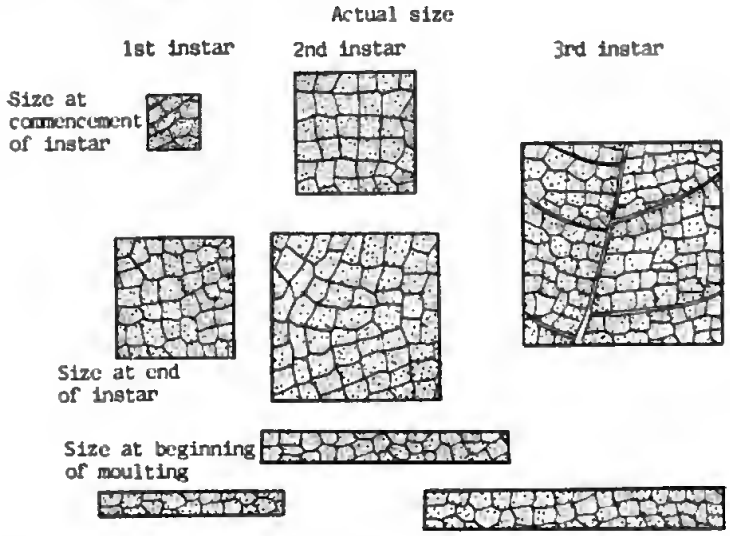
(b) Standard of leaves: The diagram below shows leaf quality required at the first three instar stages. As the mulberry growth rate in the wet season is very fast lower leaves may be used but in the dry season such leaves should be avoided.



(c) Preservation of leaves: It is frequently necessary to preserve leaves for later use and attention must be given to ensure that quality is maintained. They should be stored in a cool place out of direct sunlight under polythene or wet gunny sheets (A) to maintain low temperatures and high humidity. A free movement of air will help to preserve quality (B).

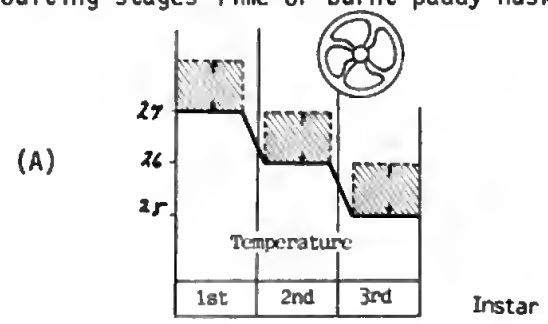


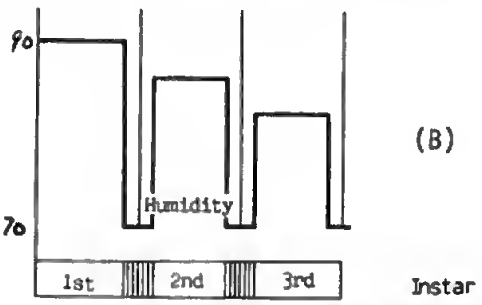
(d) Standard sizes for leaf feeding: For optimum consumption, leaves should be chopped into sizes appropriate for the easy consumption by the larvae at the various stages of development as shown below.



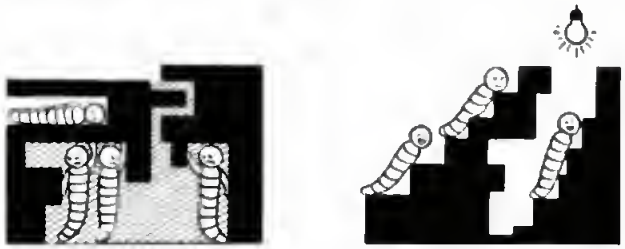
3.3.3 Environment: The physical environment in which larvae are reared is of great importance in achieving optimum growth.

(a) Temperature and humidity: The following diagrams set out the temperature/humidity requirements for the maximum development of young larvae. If the temperature is low, physiological activities are reduced, resulting in irregular growth and an increase in the larval period. If, however, the temperature is high the secretion of hormones is accelerated and also the larval duration. Diagram A shows the optimal range for each instar. To keep the rearing bed dry at the moulting stages lime or burnt paddy husks are used to bring down the humidity (B).

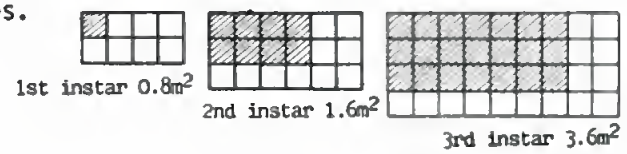




(b) Photosensitivity: Worms dislike extremes of dark and bright environments. They prefer light within the range 15-30lux and are more active at the upper level. They will come to the surface when the top area is exposed to light.



(c) Area for silkworm bed: As worms develop rapidly, from the time of the first feed precautions should be taken to avoid high densities which will inhibit full consumption and increase the likelihood of fermentation of unconsumed leaves. The diagram below shows the ideal bed/density ratio for standard 20 000 silkworm eggs at the first three instar stages.



3.3.4 Box and Paraffin Paper Rearing for Young Silkworms: With the traditional method of rearing the larvae are placed in a box and fed at least four times a day. Two more efficient and less labour-intensive methods have been developed and are discussed below.

(a) Box rearing method: Either wooden or zinc boxes may be used (see below for specifications). Standard frequency of feeding with this method is three times a day. The top cover should be opened half an hour before feeding. Temperatures below 25°C should be avoided as reduction of temperature will raise humidity within the box. At moulting apply burnt paddy husks or lime to reduce humidity.

* Size of box: The table shows space requirements for 20 000 eggs per box.

Size of box	1-2 instar	1-3 instar
60 x 90cm	3 boxes	6 boxes
75 x 105cm	2	4
90 x 180cm	1	2

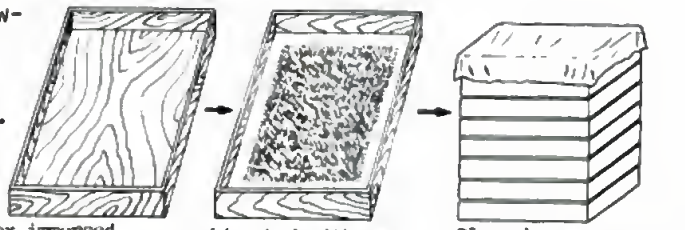
Heighth of silkworm rearing box: 12-15 cms.

* Wooden box: The diagrams show the operation of this method. The following gaps should be allowed between boxes to provide circulation of air.

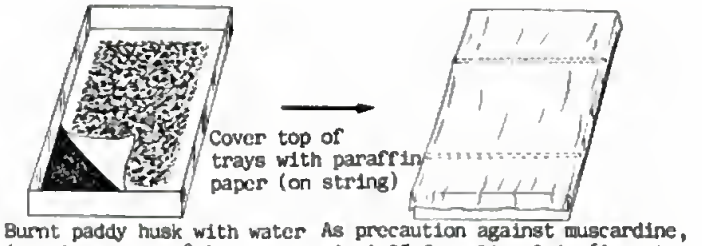
1st instar: no gap

2nd instar: 3cm

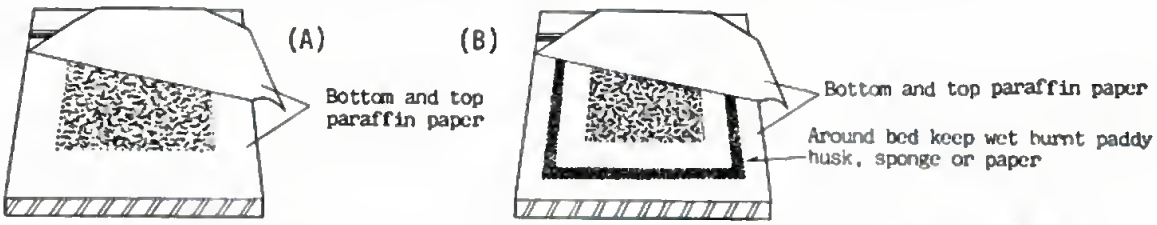
3rd instar: place boxes obliquely on stack



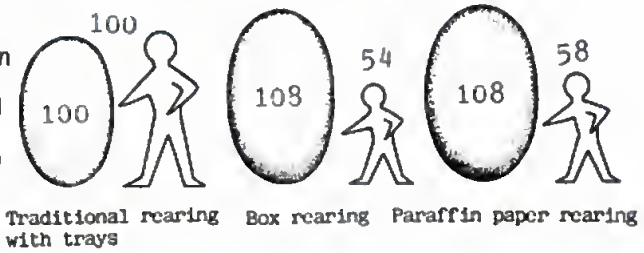
* Zinc box:



(b) Paraffin paper rearing method: In this method the rearing frames are covered with paraffin paper (pure paraffin paper with melting point above 55°C should be used; perforated paraffin paper may be used if placed 10cm above bed); the larvae are spread on the paper; and a further sheet is placed over the larvae to preserve moist conditions. Normal feeding frequency is four times a day i.e. without additional wet material (A) but with a wet band this can be reduced to three (B). The upper sheet should not touch the larvae. Wet material should not be used for 3rd instars. Burn bottom paper after use; top paper can be used again.



(c) Labour ratio: Relationship between rearing method, labour demand and cocoon yeild is demonstrated in this diagram.



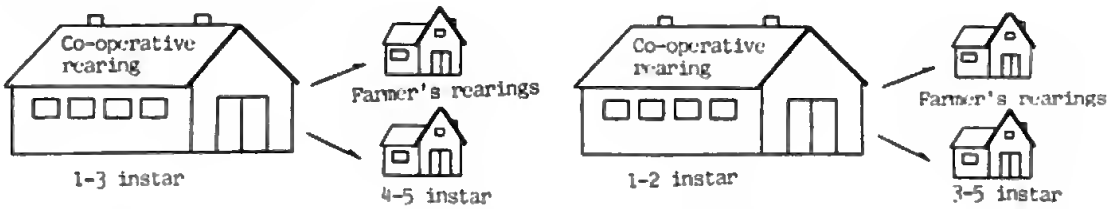
3.3.5 Co-operative Rearing for Early Stage Silkworms

(a) Advantages

* Ensures stable rearing and higher cocoon quality
* Saves labour and leaves time for other work
* Reduces expenditure and lowers cost of production
* Disease control easier
* Easier to apply new techniques
* Unity of members

(b) Requirements: Centralizing certain key operations means that a high level of administrative and technical skill is required and the central depot becomes a vital storehouse for materials and equipment. Mulberry fields under the control of the co-operative are essential for the successful operation of this system.

(c) Organization: Farmers can save tool usage and provide better management by rearing the first three instars co-operatively, followed by individual rearing of the succeeding stages.



(d) Buildings and equipment: Co-operative rearing sheds should be suitable for temperature and humidity control, easy to keep clean and free from disease and convenient for the instalment and operation of equipment. Some suitable sheds are set out below.

* Floor heating rearing shed: This is the simplest design and the cheapest to run. Ordinary box or paraffin rearing trays are placed on heated floor.
* Brick/electric floor rearing shed: Heating by electric floor cable line. Walls absorb moisture.
* Duct-heated rearing shed: Most expensive to install. Duct heating provides automatic control of temperature and humidity.

3.3.6 Young Silkworm Rearing by Artifical Diet

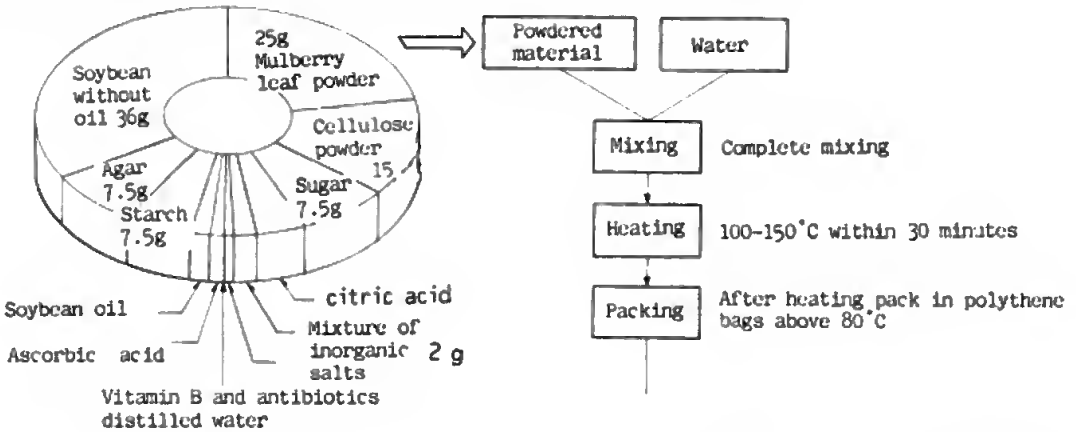
(a) Advantages

* Saves labour at rearing stage (i.e. harvesting leaves and feeding)
* Higher cocoon yield
* Sterile feed and clean environment
* No seasonal fluctuation of feed quality
* Allows mechanization of silkworm farming
* Suitable for co-operative rearing of young silkworms
* Increases efficiency of tools and facilities
* Increases in quantities dependent on facilities

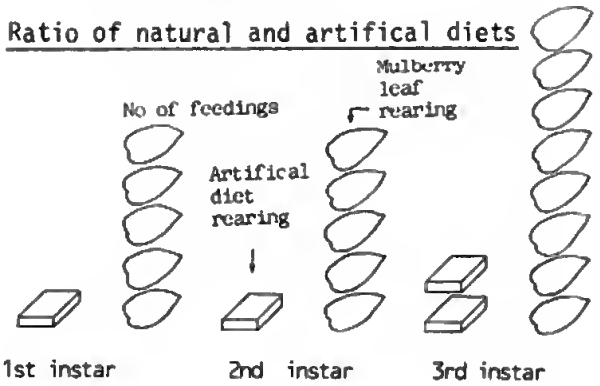
(b) Disadvantages

* Artifical feed expensive
* Greater investment in technology required

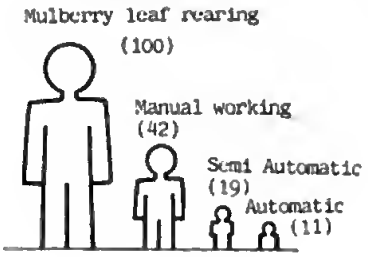
(c) Diet components and preparation: The following diagram shows the ingredients making up the artifical diet and the process of preparation.



(d) Ratio of natural and artifical diets



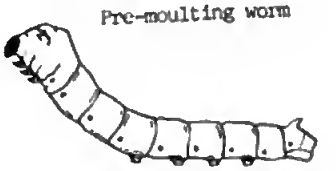
(e) Rearing method/labour ratios



3.3.7 Silkworm Handling from Pre-moulting to Post-moulting: Because of the important physiological activities during the moulting period the correct handling of the silkworms is most important at this stage.

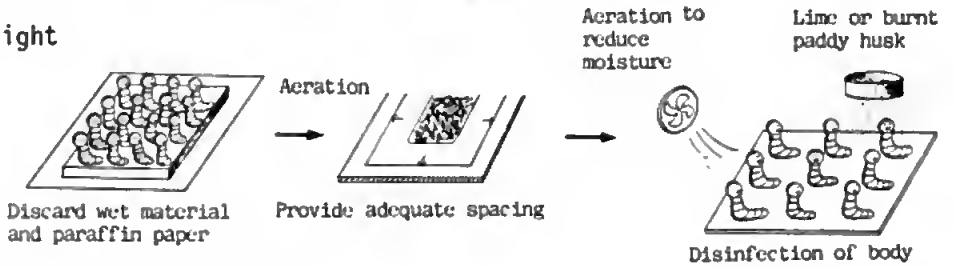
(a) Pre-moulting and moulting

Pre-moulting worm



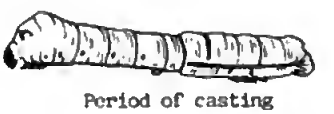
Moulting worm

* Carry out net cleaning before worms settle to moult
* Maintain dry environment and dry rearing bed by applying lime or burnt paddy husks
* Keep room dark to obtain uniform moult
* Lower temperature (needed before and after moult)
* Reduce moisture to 65% - 70%
* Avoid high fluctuations of temperature and humidity as well as strong winds and bright light



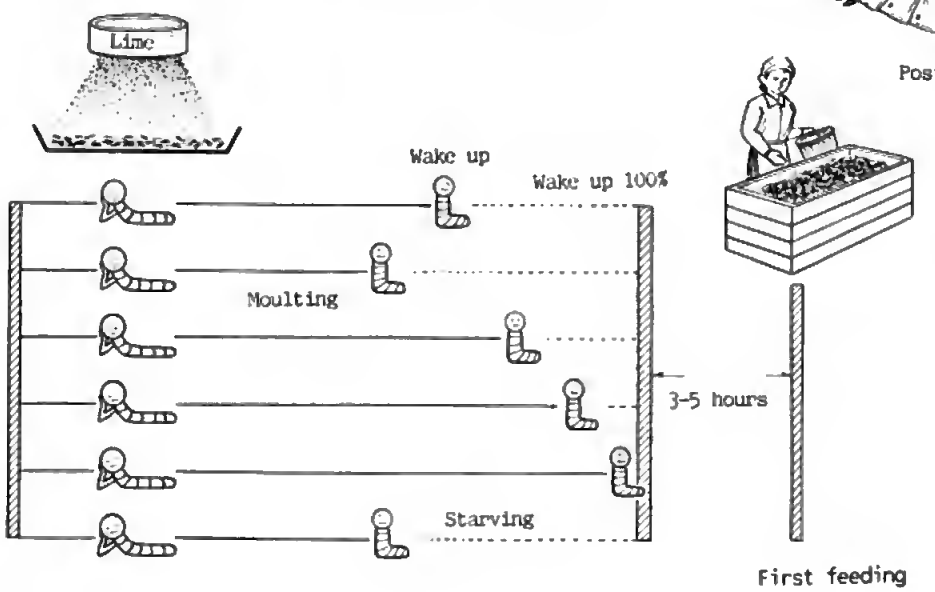
(b) Casting and post-casting of skin

* Increase humidity after casting
* First feed after moult should be sufficient to satisfy appetite completely
* Use soft leaves for first feed after moult



Period of casting

Post casting skin



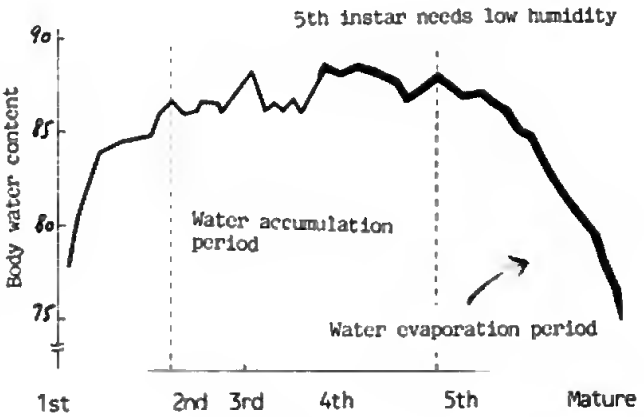
3.4 REARING OF ADVANCED SILKWORMS

3.4.1 Physiological Activities at 4th and 5th Instar Stages: When the silkworm moves into the advanced larval stage (i.e. 4th and 5th instars) physiological activities change markedly. The 4th instar grows rapidly and in the 5th instar stage most of the silk production takes place.

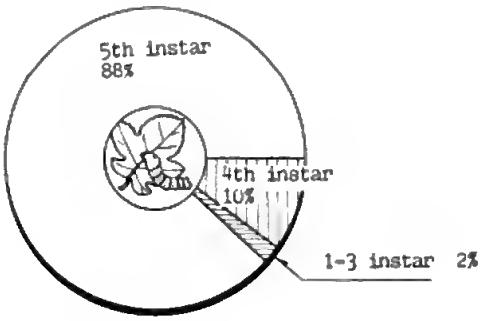
(a) Temperature: The optimum temperature for growth is 24°C for 4th instars and 23°C for 5th instars. Below 20°C the 4th instar duration is longer than the 5th and will result in a light crop. However this temperature affects the 5th to a lesser degree.

(b) Virus resistance: As the larvae mature resistance to viral disease such as grasserie and flacherie becomes significantly greater (see 4.4). Viral disease from 5th instar to is caused by infection during the 4th instar when resistance is significantly less. The 4th instar needs the same preventive measures as the 1st-3rd instars.

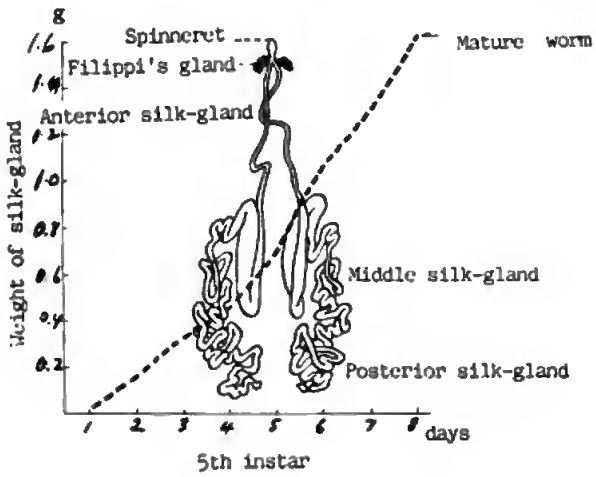
(c) Water content in adult larvae: Water requirements vary according to stage of development: 5th instar worms feed on leaves containing 78-80% water; as they mature this should reduce to 75% and a dry and breezy environment provided.



(d) Consumption of leaf: The pie-chart shows the relative demand for leaf for growth at the various stages. The demand at 5th instar is very much greater than at all previous stages.

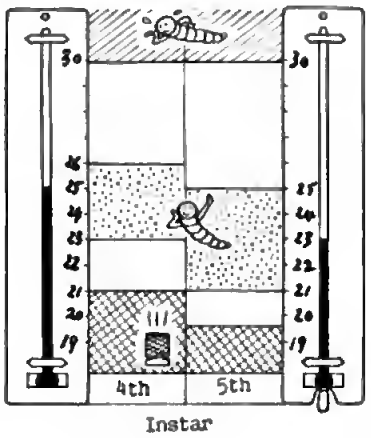


(e) Structure and growth of silk-gland at 5th instar: The graph below shows the daily growth of the silkworm gland by weight; the diagram indicates the structure of the silk-gland.

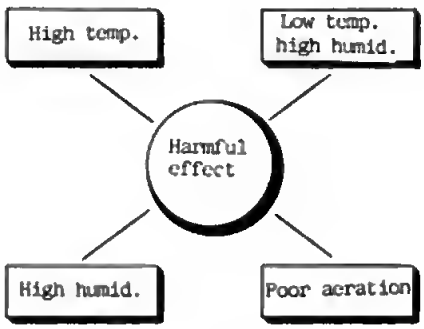


3.4.2 Environment: Temperatures below 20°C at 4th instar and above 30°C at 5th instar destroy the physiological activities, resulting in poor crops. At the late stage it is necessary to control temperatures and humidity by means of air circulation.

(a) Temperature control: Diagram A shows the ideal temperatures for 4th and 5th instars, as well as the negative levels. Diagram B sets out the environmental factors likely to produce harmful effects on late stage worms.



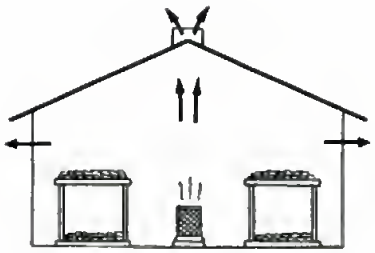
(A)



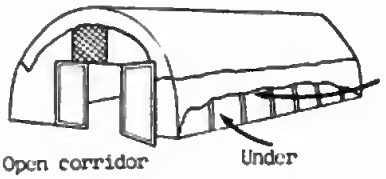
(B)

(b) Rearing rooms to control temperature/humidity: To ensure optimum conditions of temperature and humidity one of the following rearing sheds may be used depending on external conditions.

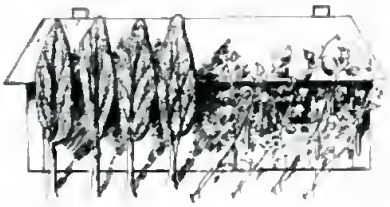
* Suitable for areas of low temperatures and low humidity: Rearing house will have to be heated artificially but care will also have to be taken to ensure proper ventilation.



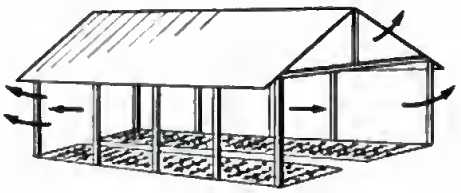
* Suitable for areas of high temperatures and drying conditions: To counter these conditions the open corridor shed provides a continuous flow of air; the silkworm bed should be covered with a sieve net and in extreme dry conditions the net should be dampened with water.



* Suitable for areas of high temperatures and humidity: To protect the rearing shed from direct sunlight plant trees around the shed and screen with gunny etc. (A); to cool, a perforated pipe may be fitted along the centre of the roof to provide a constant spray of water. Good air circulation will reduce body temperature of the silkworm (B).



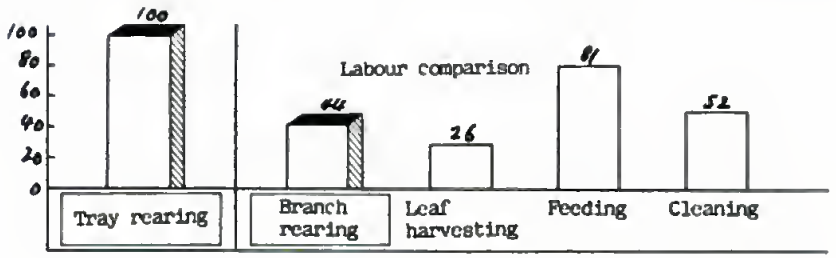
(A)



(B)

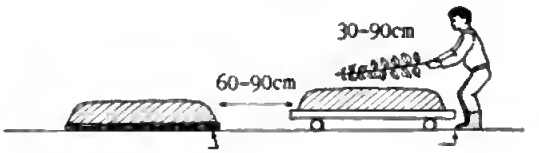
3.4.3 Branch Rearing: Method of feeding where the whole branch is placed on the rearing tray, only suitable for advanced silkworms.

(a) Comparative labour demands for various activities in silkworm rearing

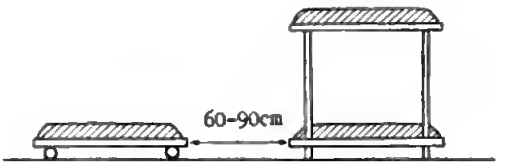


(b) Shelves for branch rearing: A variety of shelving systems is available depending on such factors as shed capacity, labour availability, etc.

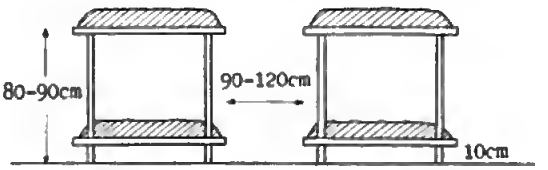
* Single shelf rearing: For working efficiency and maintenance of hygienic conditions beds should be raised a little above the ground.



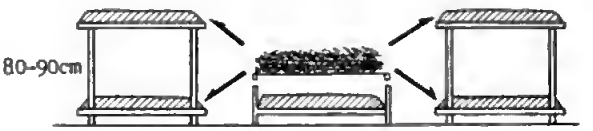
* One and two shelves alternate rearing



* Double shelf rearing



* Double shelf rearing with trolley: Trolley makes feeding easier and saves time but is costly.



* Specifications for shelves

Shelf system	Height above ground	Working space	Bed width	Feeding efficiency
Single shelf	10cm	30-90cm	150cm	100
Double shelf	1st shelf - 10cm 2nd shelf - 80-90cm from 1st	60-120cm	120cm	110
Triple shelf	1st shelf - 10cm 2nd shelf - 60cm from 1st 3rd shelf - 60cm from 2nd	90-150cm	120cm	130

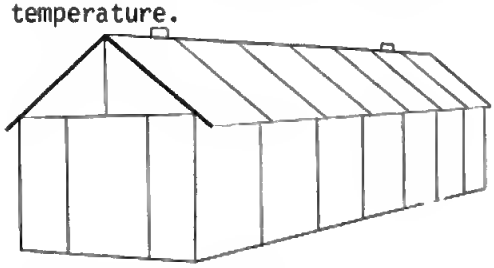
(c) Density of silkworms: Most common density of larvae is 110-130 worms per 0.1sq m but to increase labour efficiency it may be increased to 150. The following diagram sets out the density/shelf area ratio.

No. of silkworms per $0.1m^2$	1.2m shelf width	1.5 shelf width	1.7 shelf width
110	13.7m	10.9m	9.6m
130	11.5m	9.2m	8.1m
150	10.0m	8.0m	7.1m
170	8.8m	7.1m	6.2m

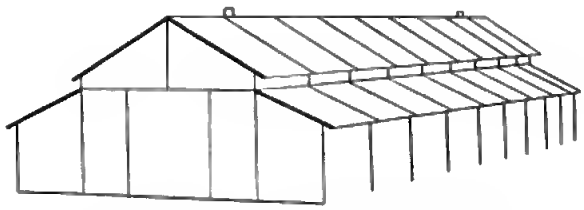
(d) Rearing houses for branch method: The following table shows an economical double-shelf branch rearing operation (for 10 boxes).

	Area(m^2)	Possible use	Box no.	Remarks
Standard rearing house	66	1-4 instar rearing	10	* Provision for heating
		5 instar rearing	5	
		Mounting	10	* Racks and shelves easily assembled and removed
Simple rearing house	66	5 instar rearing	5	
Mulberry leaf storage	16.5	1-5 instar rearing		
Total	148.5	1	10	* Ceiling raft for mounting frames

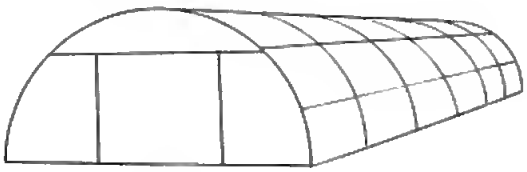
* Simple rearing houses: The following designs illustrate rearing houses of minimal cost though the adoption of a particular model will depend on local conditions. A simple rearing house should be made of economical material (e.g. aluminium sheet) that refracts sunlight. Because of constant temperature fluctuations there should be corridors which can be opened and closed to control temperature.



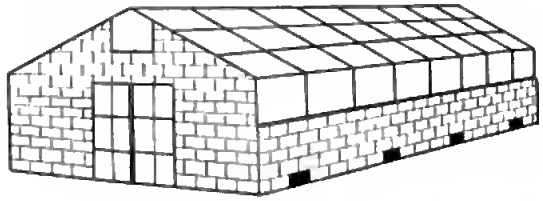
Steel or wooden pillars



More rearing space during non heating period

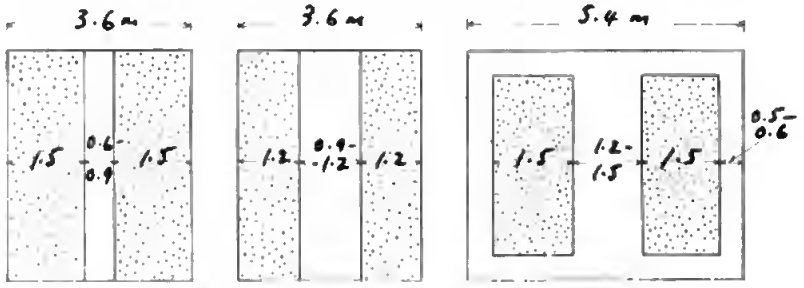


Polythene house type



Simple rearing house with bricks and pipes

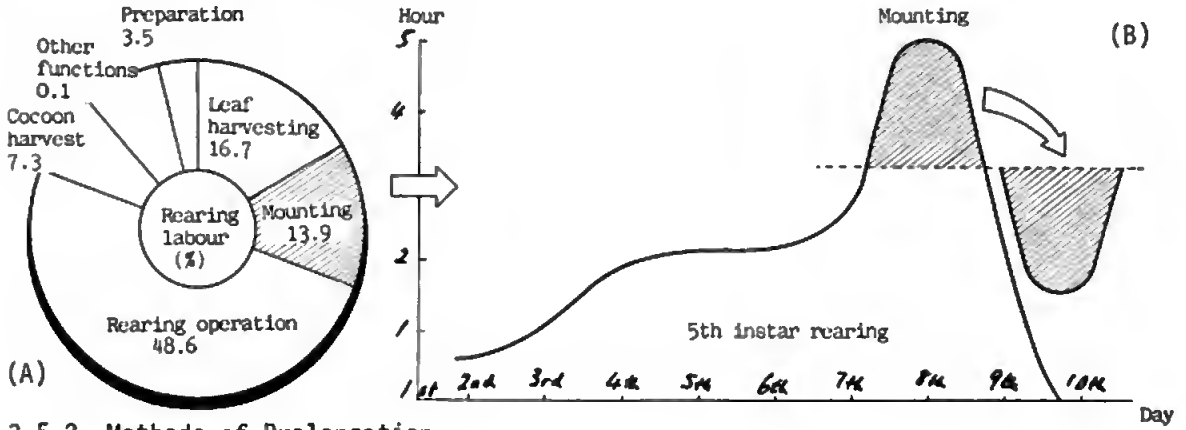
* Arrangement of rearing house for branch rearing: There are big differences in rearing quality and working efficiency of a given area depending on size of beds, working space, number of shelves, side passages etc. The following are some suitable arrangements.



Single shelf rearing Double shelf rearing Passage on either side

3.5 MOUNTING

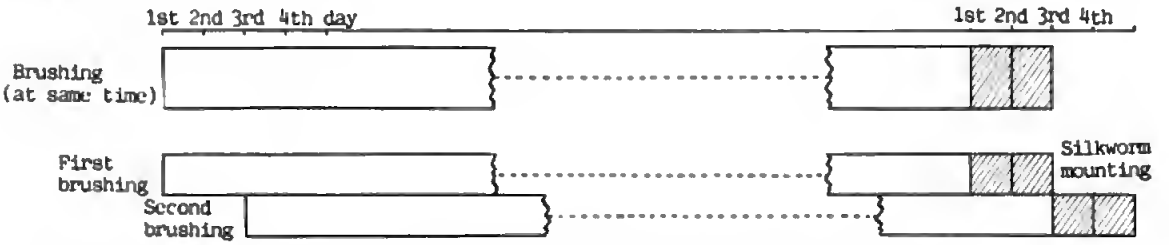
3.5.1 Manipulation of Larval Duration to Disperse Labour Demand: After completing the larval stage the silkworms are placed on frames for the production of cocoons. The pie-chart below shows the labour demand for mounting in relation to the the whole rearing process (A). The graph (B) shows how, by splitting mounting batches, the labour demand can be dispersed.



3.5.2 Methods of Prolongation

(a) Control by temperature manipulation: The 5th instar can be extended or reduced by one or two days by lowering or raising the temperature.

(b) Arrangement by silkworm brushing: If brushing is carried out twice with an interval of two days, mounting work is spread over about four days and labour is thereby dispersed. Suitable for large-scale farms. The diagram shows how this is achieved.



(c) Rearing batches in different ages: At fourth moulting silkworms are divided into early and late growing silkworms, one group is manipulated to grow early and the other late so that an interval of about two days is created. This helps the silkworms grow uniformly and mounting labour is also dispersed.

3.5.3 Mounting by Shaking

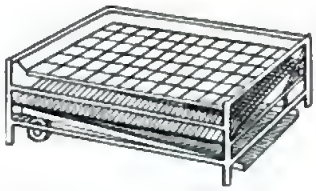
(a) Separate worms into batches: Even in a normal and uniform batch time of maturing may differ by 10-15 hours. To maintain uniform growth, at 4th moult segregate the worms into early, middle and late batches or early and late for 5th instar worms.

(b) Place straw rope or net on bed the day before mounting starts. Place fresh branches on the straw or netting. The fresh feed will attract the larvae.

(c) Pick early maturing worms by hand: The developed larvae -- about 10% -- will not eat and should be hand picked and mounted. The remaining larvae are then given the opportunity to mature, for example, over night. The following day they will be ready to be shaken.

(d) Shaking: The straw or netting frame is then taken either to the automatic shaking machine (A) or to the shaking stand (i.e. for hand shaking) (B); the worms are then separated from the frames or branches and are ready for collection (C).

(A)

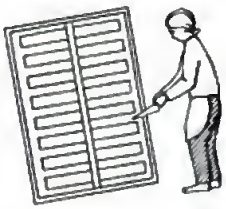


(B)

(C)

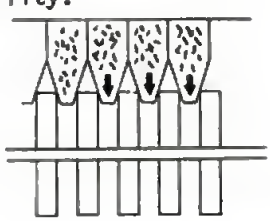
(e) Collection and mounting: After collection the worms are then placed on mounting frames by a variety of methods: the horizontal/oblique method (A) produces the best cocoon reelability; the horizontal method (B); and the multiple-pan method (C), the least satisfactory for reelability.

(A)



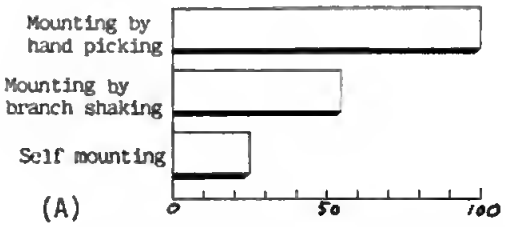
(B)

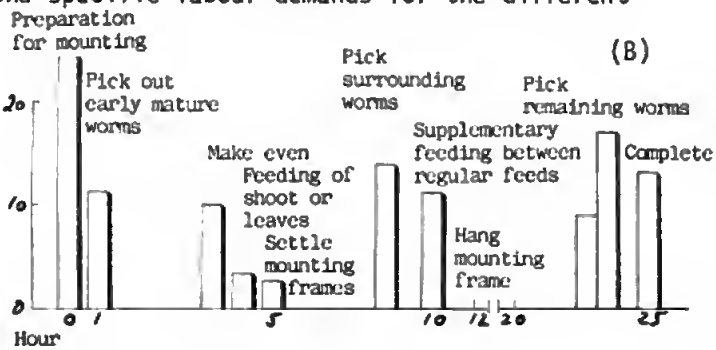
(C)



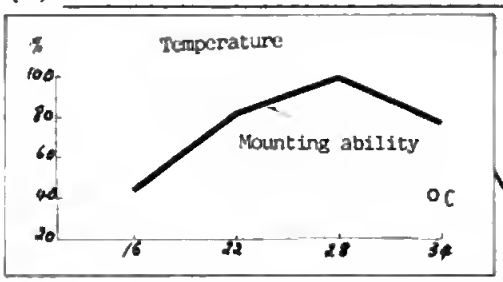
3.5.4 Self Mounting: This method is easy and labour saving but it is difficult to obtain a 100% success rate as it depends on natural conditions. In addition it involves collection and handling.

(a) Efficiency: The following graphs indicate the relative labour demands of the various mounting methods (A); and the specific labour demands for the different stages of self mounting (B).

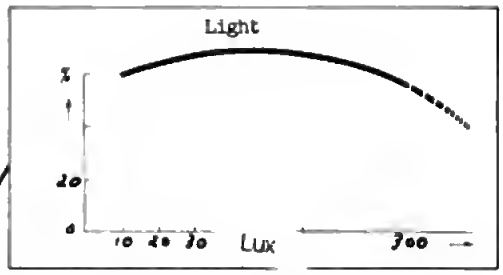




(b) Conditions for successful self mounting

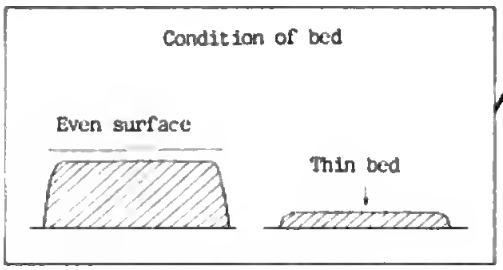


24-28°C ideal temperature; mounting ability increases up to 28°C

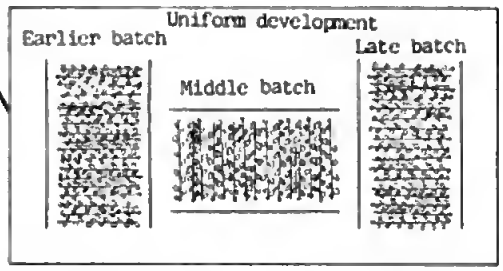


Excess light reduces climbing ability; suitable dim light for climbing 20-30 lux

Basic conditions

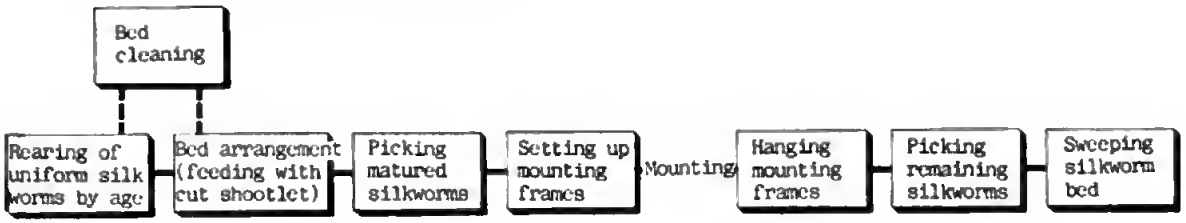


Even surface and thin bed without gaps accelerate climbing ability of worms

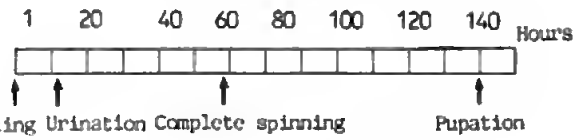


Rapid settlement and climbing ability increase if growth is uniform

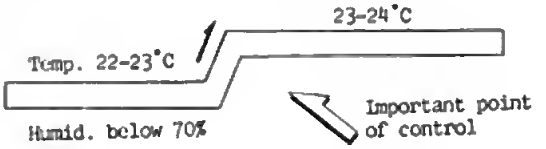
(c) Order of self-mounting process



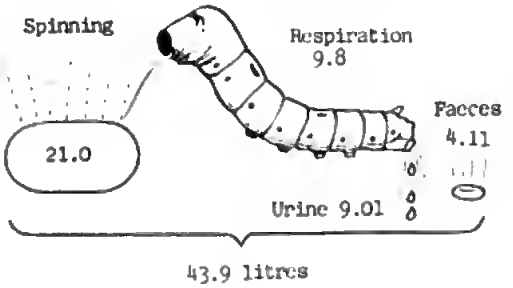
3.5.5 Precautions at Mounting Stage: Maintenance of proper atmospheric conditions, especially during the first three days, is essential for good reelability and quality silk.



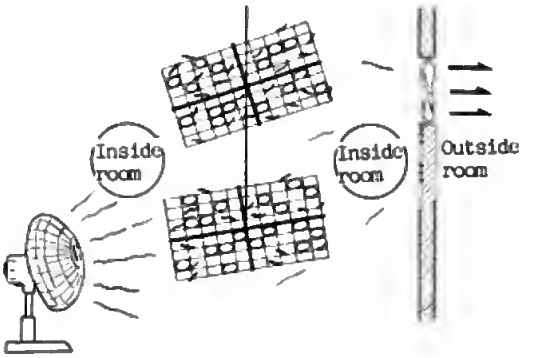
(a) Mounting cycle: Diagram shows the mounting cycle in relation to temperature/ humidity for maximum productivity. Until completion these levels must be maintained at a constant level.



(b) Temperature/humidity control: Humidity control at the mounting stage must take into consideration the quantity of the moisture created by the silkworms themselves (A). Ventilation is also important as the higher the air current, the better the reelability (B) -- keep air current within 0.2m/sec. in the mounting room (C). Room must be heated if necessary.

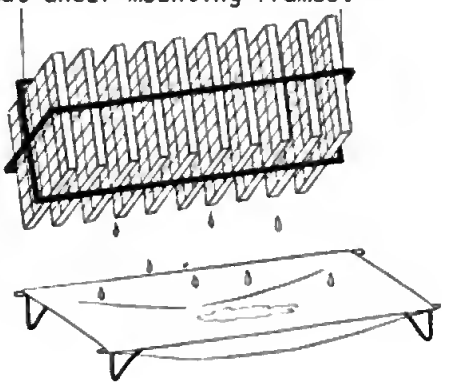


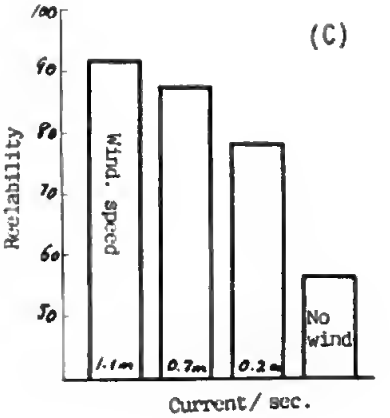
(A)



(B)

(c) Urine and excreta removal: To avoid excessive moisture in mounting room collect urine etc. in paper mat under mounting frames.

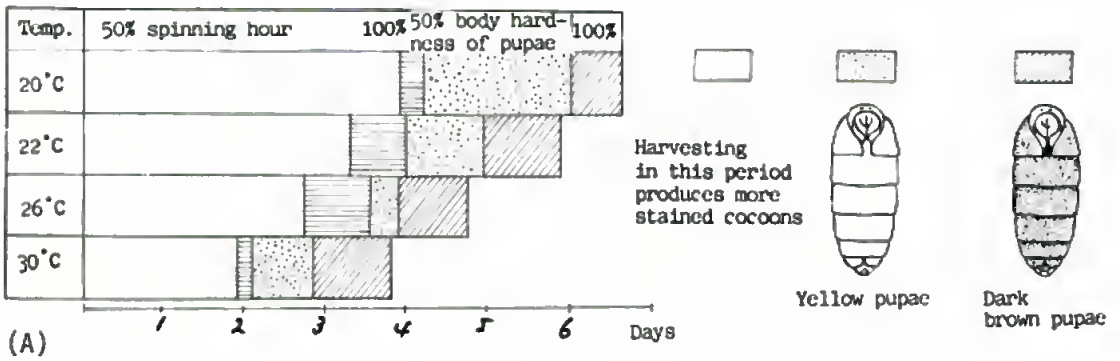




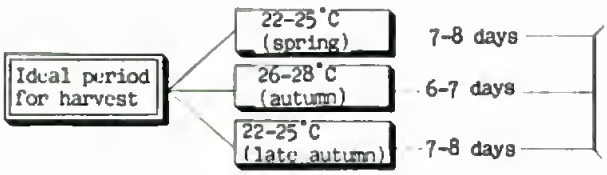
(C)

3.6 COCOON HARVESTING AND SORTING

3.6.1 Harvesting: Best harvesting period is from 6th to 8th day after mounting when the pupal skin is hard. Early harvest when skin is soft and yellow can cause injury to the pupa and stain the cocoon. Diagram A shows the relationship between temperature and spinning/pupation. Pupae should always be checked for hardness. Diagram B shows ideal harvest period.

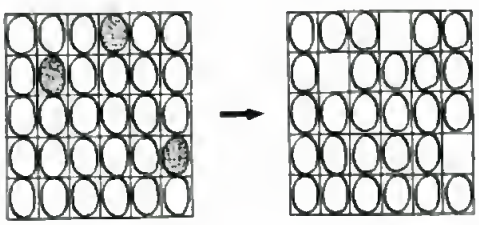


(A)

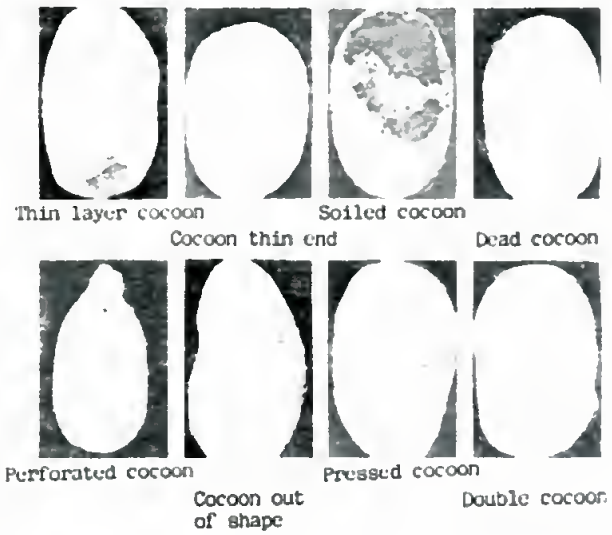


(B)

3.6.2 Sorting: This process greatly affects the price of cocoons. To increase reeling efficiency only good cocoons should be selected for sale. Remove all deformed, flimsy and dead cocoons before harvesting (A). Types of defects are shown in B.



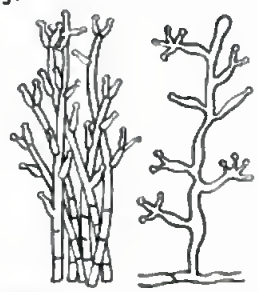
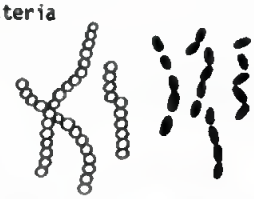
(A)



(B)

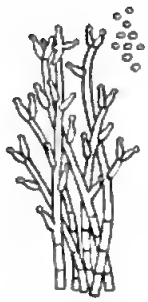
Chapter 4: SILKWORM DISEASES AND THEIR CONTROL

4.1 SILKWORM DISEASES AND PESTS

PATHOGEN	NAME OF DISEASE	SEASON/STAGE	PATHO-GENICITY
Fungi 	White muscardine	Spring, autumn; larva, pupa	Chronic
	Yellow muscardine	Spring, autumn; larva, pupa, moth	Chronic
	Green muscardine	Young larvae in autumn	Chronic
	Aspergillus disease	Young larvae spring & autumn	Chronic
	Black muscardine	Young larvae in autumn	Chronic
	Brown muscardine	Very rare	Chronic
Bacteria 	Sotto disease	Any season and stage	Acute
	Septicaemia	Any season and stage	Acute
	Bacterial diseases of of digestive organs	Bacteria and infectious virus increase pathogenicity by double infection of both pathogens — Grown larvae in autumn	Chronic
Viruses	Infectious virus flacherie	Grown larvae in autumn	Acute / Chronic
	Nuclear polyhedrosis	Spring, autumn; grown larvae	Chronic
	Cytoplasmic polyhedrosis	Spring & autumn; young/grown larvae	
	Mid-gut nuclear polyhedrosis		
(Microsporidea) Protozoa	Pebrine	Spring, autumn; larvae, pupa, moth	Chronic
Pests	Silkworm pests	Summer & autumn; grown larvae	Chronic

4.2 MUSCARDINES

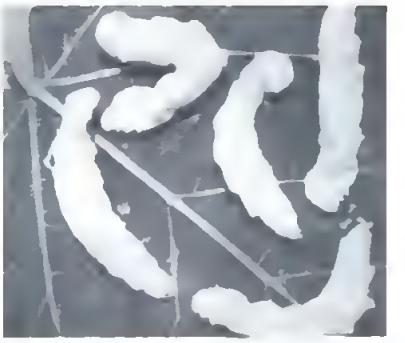
4.2.1 Classification of Muscardines: In muscardine infection conidia germinate penetrating the body of the silkworm where they multiply and sap the body fluids, eventually causing death. Then the hyphal bodies in the dead silkworm produce mycelia and conidia which cover the body as a thick layer -- called muscardines.

Name	Scientific name of pathogen	Shape of hypha	Size/shape of conidium	Temperature & germination time for conidia	Season/stage of disease occurrence	Latent period of pathogen
WHITE MUSCARDINE	Beauveria bassiana		2.5-3-4.5 x 2.3-3.3-4.0 Spheric or oval	25-28°C 4-8 hours	Young larvae, grown larvae & pupae in spring rearing season	Young larvae 5 days; grown larvae 6-7 days
YELLOW MUSCARDINE	Beauveria bassiana		2.0-2.9-3.1 x 1.5-2.5-3.5 Oval or spherical		Young larvae, grown larvae, pupae & moths in spring & autumn	Young larvae 6 days; grown larvae 9-10 days
GREEN MUSCARDINE	Nomuraea rileyi		3.5-4.0-5.2 x 2.0-2.5-3.2 Oval or round	22-23°C 12-20 hours	Young larvae in autumn	Young larvae 11-12 days; grown larvae 13 days
ASPERGILLUS DISEASE	Aspergillus spp.		4-8 Round		Young larvae (1st & 2nd stages)	Young larvae 5 - 7 days

4.2.2 Symptoms and Infection Route

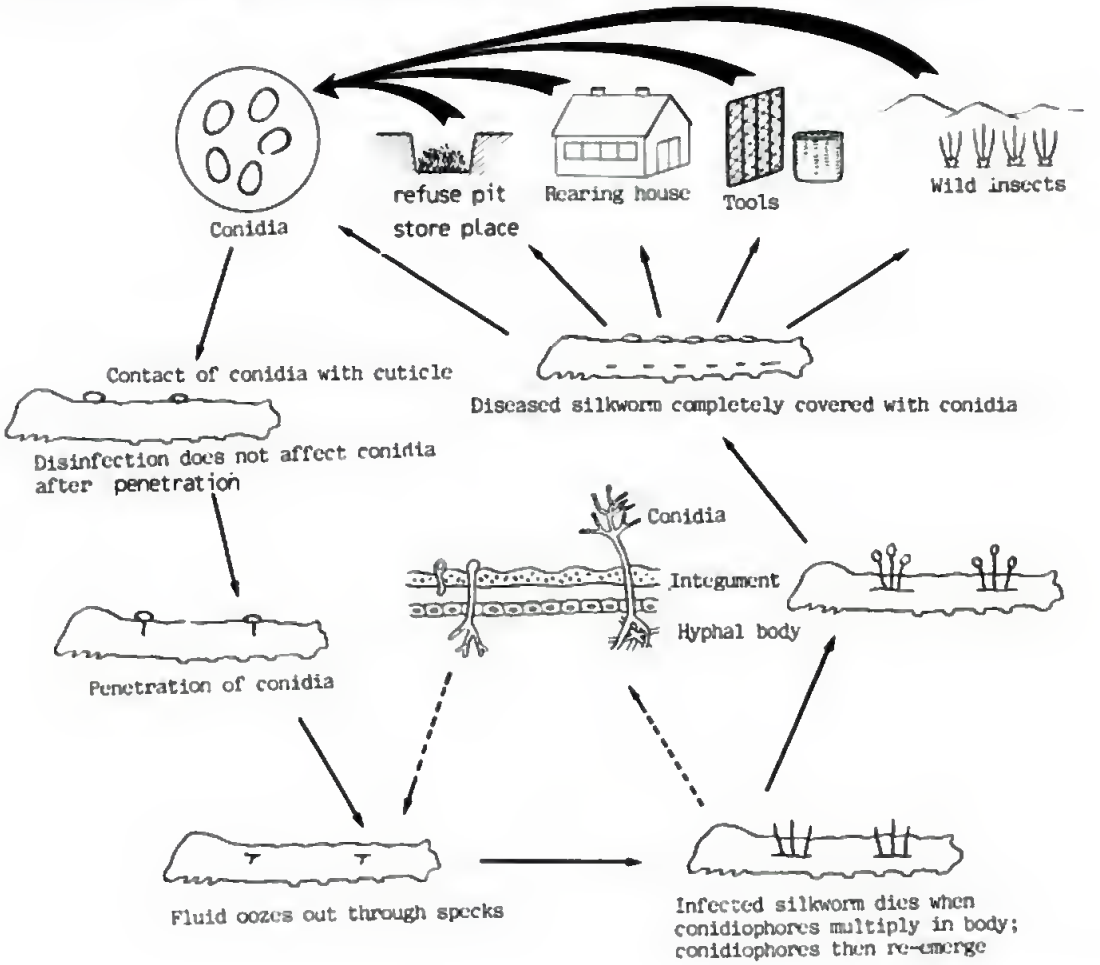
(a) Symptoms: Infection takes place mainly through the skin due to body contamination. When the disease advances, specks of an oosing oil substance appear on the surface (A). B shows worms affected by white muscardines.

(A)



(B)

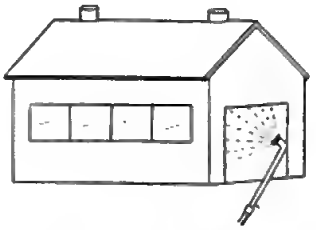
(b) Infection Route: In humid conditions the risk of muscardine infection is high and likely breeding places must be properly treated to prevent infestation. The following diagram shows infestation cycle and likely breeding grounds.



4.2.3 Control of Muscardine Infection: To control the disease it is most important to keep the moisture level as low as possible which may be achieved by using disinfectant powder (mixture of paraformaldehyde and lime). Disinfection of rearing room and tools is an important preventive practice. Once larvae has been infected it is important to separate them immediately from the healthy worms.

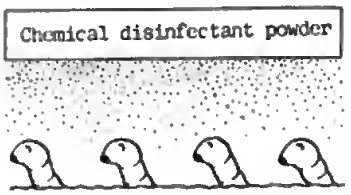
(a) Control measures

* Rearing room: Disinfect with sodium hypochlorite solution before brushing and rearing.



* Tools: Dip tools in solution of high-grade chlorinated lime 1:200. The tools should be retained in the solution for at least two hours and then cleaned.

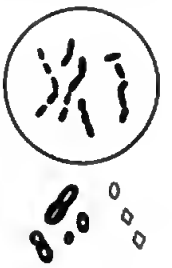
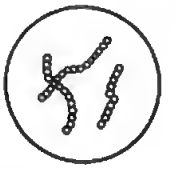
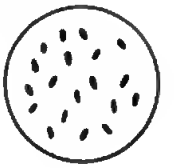
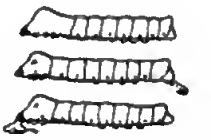
(b) Silkworm body disinfection: Larvae should be dusted with disinfectant powder (paraformaldehyde and lime) after the mulberry leaves have been eaten as the powder will harm the larvae if consumed.



Amounts required for stages on one box of silkworm eggs

Date	Area (m^2)	Chemical per $0.1m^2$	Chemical required
1st stage 1st day	0.1	1.5g	1.5g
" " 2nd "	0.6	2.0	12
2nd " 1st "	1.2	2.5	30
" " 2nd "	1.8	2.5	45
3rd " 1st "	3.6	2.5	90
" " 3rd "	3.6	2.5	90
4th " 1st "	6.0	4.0	240
" " 3rd "	9.0	4.0	360
5th " 1st "	9.0	5.0	450
" " 3rd "	15.0	5.0	750

4.3 BACTERIAL DISEASES

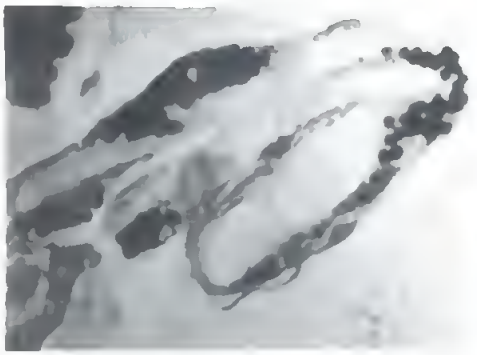
Name of disease	SOTTO DISEASE	SEPTICAEMIA	BACTERIAL DISEASE OF DIGESTIVE ORGANS
Pathogen	Bacillus thuringiensis var. sotto 	Small & large bacilli Streptococci Staphylococci 	Various kinds of bacteria 
Infection stage	Larva	Larva, pupa, moth	Larva
Infection route	Through mouth	Through an injury	Through mouth
Site of pathogen multiplication	Blood & alimentary canal	Blood	Alimentary canal
Incubation period	Short	Short	Long
Correlation with silkworm health	None	None	Yes
Symptoms	Lack of appetite Sluggishness Lack of skin tension Diarrhoea Loss of grasping power of prolegs	Loss of grasping power of prolegs Vomitting fluid Lack of appetite	Loss of appetite Sluggishness Diarrhoea Vomitting fluid 

4.4 VIRAL DISEASES

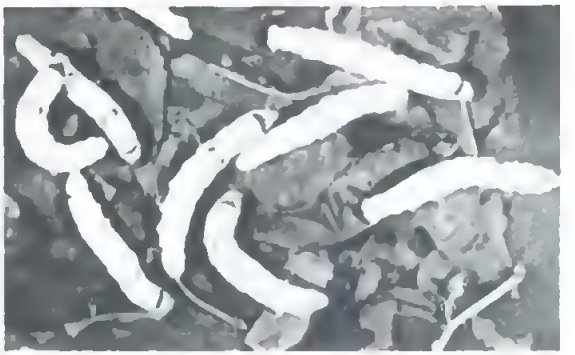
Name of disease		Grasserie (Nuclear polyhedrosis)	Cytoplasmic polyhedrosis (Mid-Gut Disease)	Infectious flacherie
Pathogen		Nuclear polyhedrosis virus	Cytoplasmic polyhedrosis virus	Flacherie virus
Characteristics of viruses	Inclusion body	Yes	Yes	No
	Shape			Spherical shape
	Size	0.5-15	0.5-15	27 nm
Virus particles in inclusion bodies				
Nucleic acid of virus		DNA	RNA	DNA or RNA
Sites of virus infection & multiplication		Nuclei of adipose tissue, tracheal epithelium, fatty body, blood cells	Cytoplasm	Goblet cells (FV) Columnar cells (NV)
Symptoms		Loss of skin tension Intersegmental membranes become swollen Skin becomes shiny Haemolymph becomes turbid When skin is ruptured, milky haemolymph blows out	Loss of appetite Mid-gut becomes whitish Head sometimes disproportionately large	Loss of appetite Larvae become blackish

4.4.1 Grasserie (Nuclear Polyhedrosis Virus, NPV)

(a) Symptoms: This viral disease begins with the ingestion of polyhedra or free viruses into the alimentary tract of the silkworm (A). It is believed that the alkaline of the silkworm mid-gut dissolves the polyhedra and the virus particles invade the cells of the susceptible tissues. The diseased larvae lose appetite and skin tension is lost. They also become restless and impatient (B).

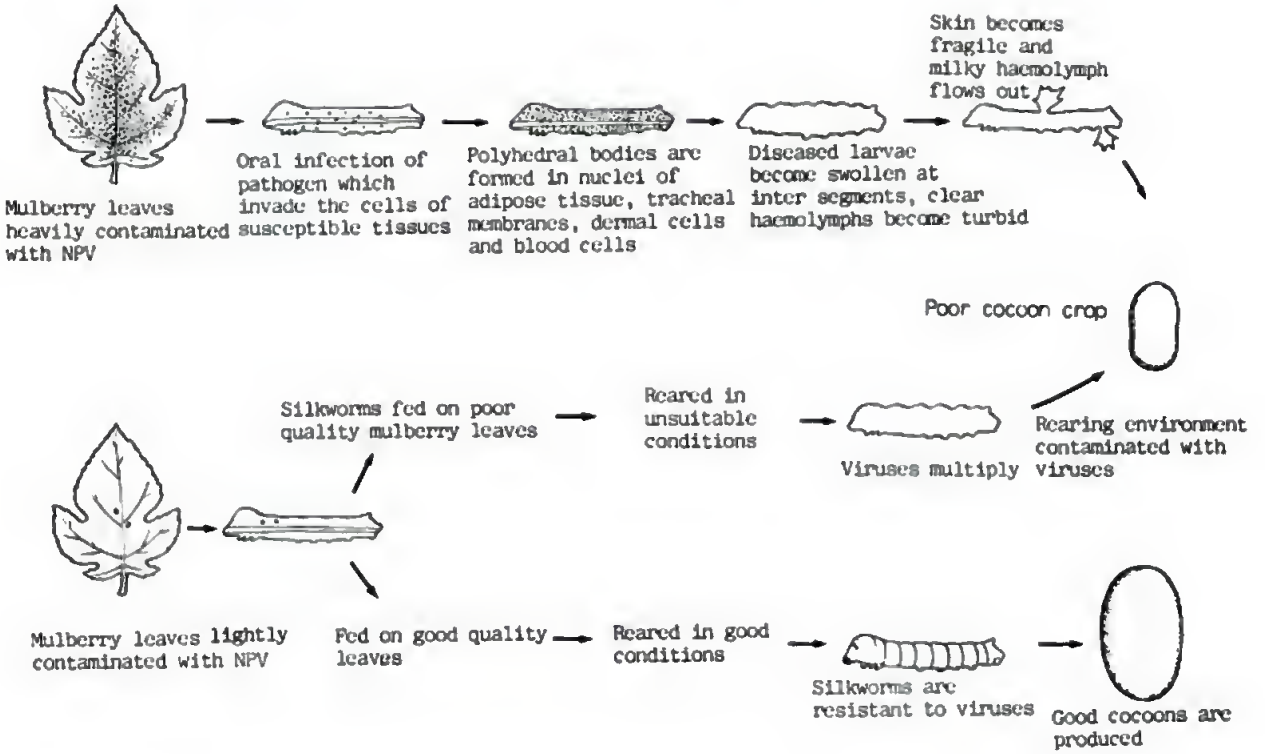


(A)



(B)

(b) Infection route



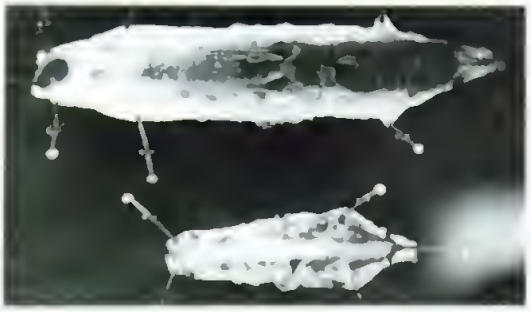
(c) Control measures

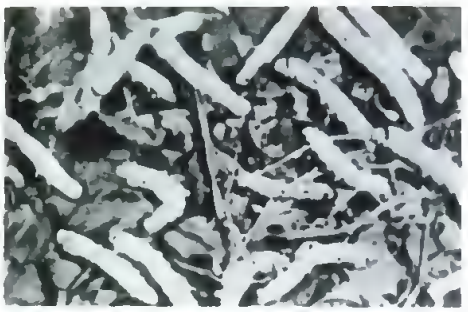
* Rear larvae under hygienic conditions
* Avoid using poor quality leaves
* Ensure proper ventilation and spacing
* Remove and destroy infected worms
* Avoid very high or low temperatures

4.4.2 Cytoplasmic Polyhedrosis Virus Disease

(a) Symptoms: Infected larvae have difficulty moulting; the gut shrinks (A) and become whitish in colour (B).

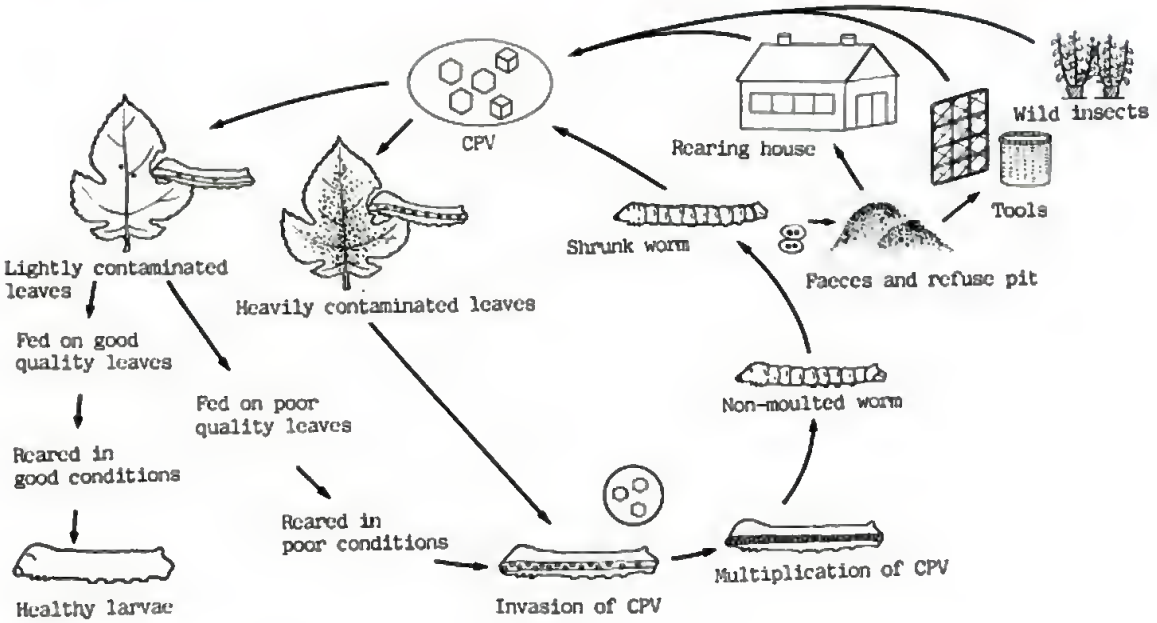
(A)





(B)

(b) Infection route



(c) Control methods

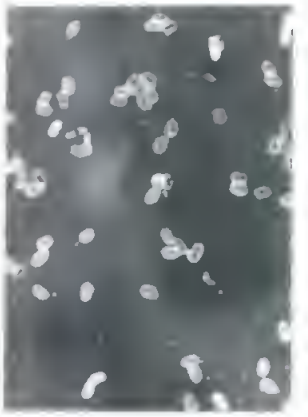
* Disinfect rearing rooms
* Separate infected larvae
* Use good quality leaves
* Ensure correct temperatures

4.5 PEBRINE DISEASE

(a) Symptoms: Infected larvae are not capable of moulting or growth (A); scattered black spots appear on the skin (B). Pathogen illustrated (C). When larvae are infected at egg stage they will all die before reaching 4th instar stage; if they are infected later then some will die before or during pupation but most will complete the cycle and themselves produce eggs which are infected.

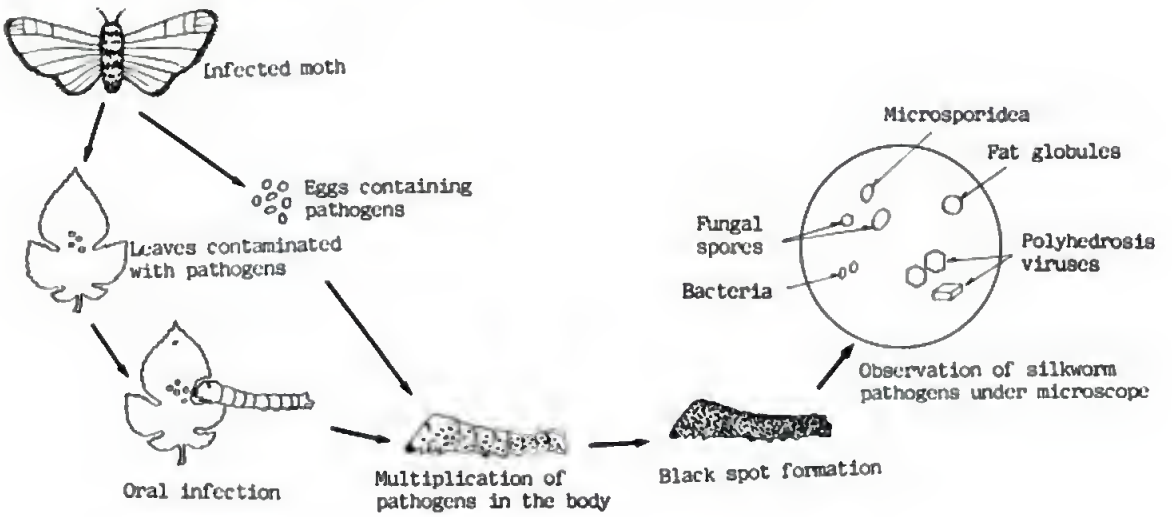
(A)

(B)



(C)

(b) Infection route: Pebrine is a microsporidean disease which is transovarially transmitted and therefore threatens the subsequent generation. For this reason it is most important to prevent it from becoming established.

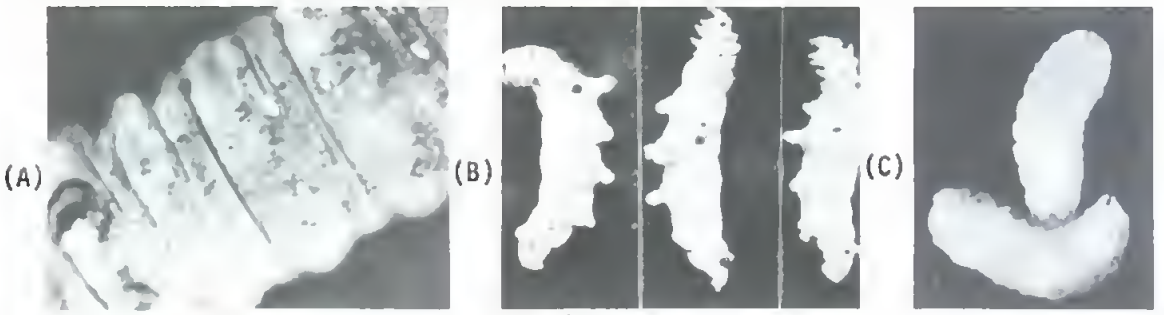


(c) Control measures: (see 4.4.3) To prevent ovarine transmission examine (1) moth after laying eggs; (2) during incubation period hatch sample eggs early and examine; (3) after hatching take samples from time to time for examination.

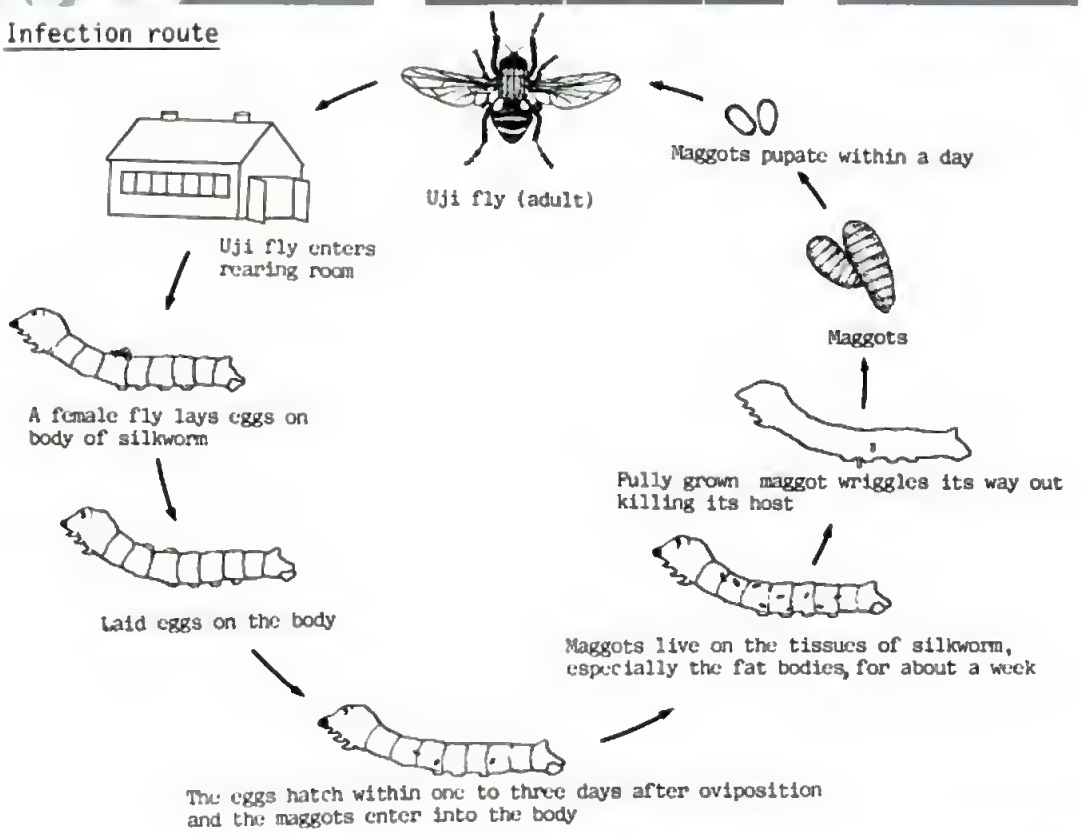
4.6 SILKWORM PESTS

4.6.1 Uji Fly

(a) Symptoms: Female lays eggs (glossy, white, oval) on silkworm body (A); black spots on body of silkworm show point of entry of maggots (B) which sap body fluids and destroy the organs, killing the larva. The fly usually attacks 4th and 5th instars to enable it to complete its own cycle. Maggots shown (C).



(b) Infection route

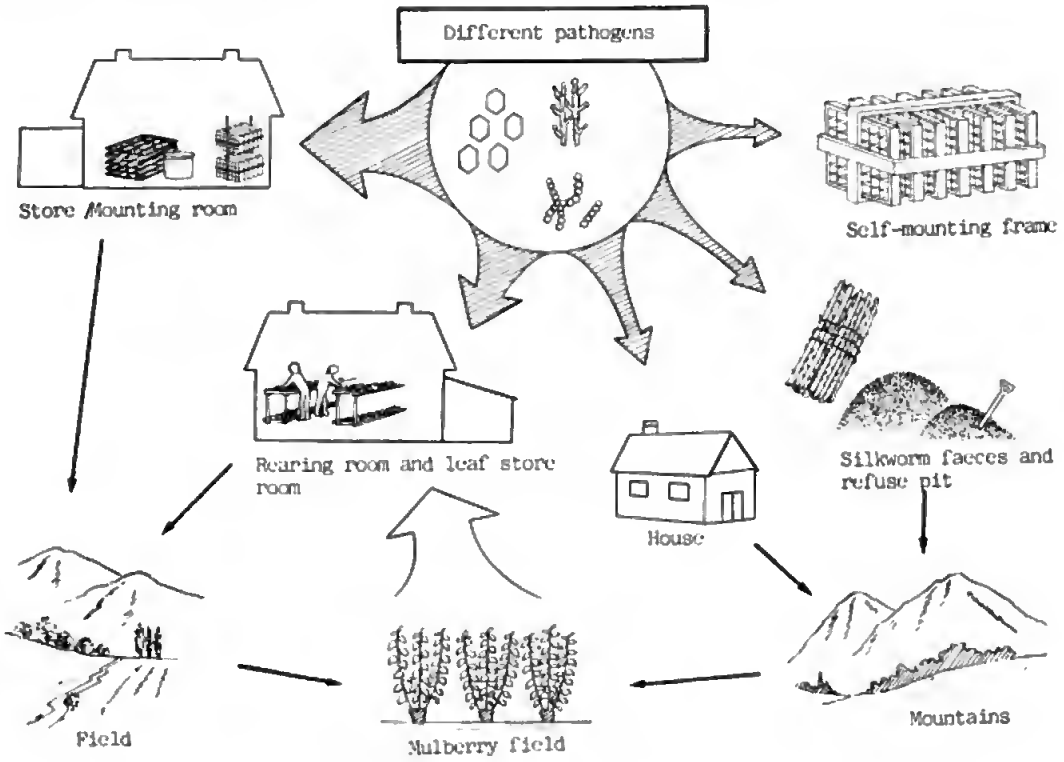


(c) Control measures

* Prevent entry of fly into rearing room
* Destroy maggot-infested larvae and cocoons
* Eradicate flies actually in rearing room

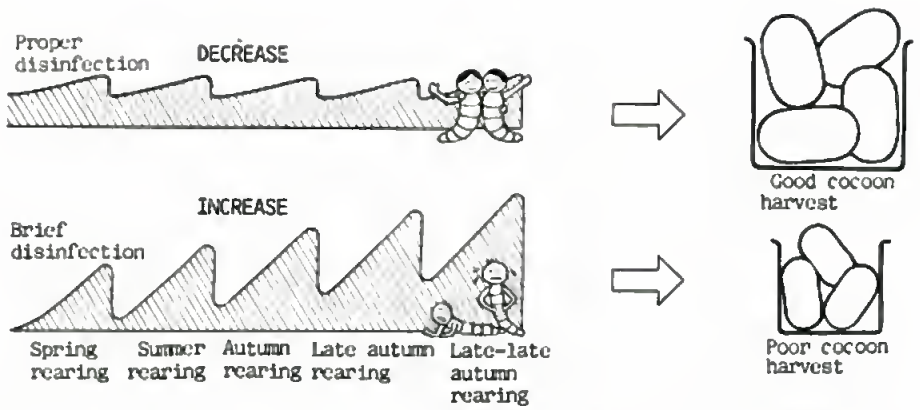
4.7 PREVENTIVE AND CONTROL MEASURES

4.7.1 Pathogen Contamination: The mounting room is the most likely place for contamination though many other potential breeding grounds exist.



4.7.2 Disinfection: Silkworm rearing rooms, tools and other equipment used in the rearing of silkworms are liable to contamination by pathogens. It is necessary therefore to disinfect thoroughly to kill them before starting rearing. Once larvae have been infected with a disease it is not possible to cure them, so that preventive measures are particularly important in silkworm cultivation.

(a) Importance of disinfection: The following diagram shows how regular and thorough disinfection reduces the density of pathogens thus ensuring a better harvest.



(b) Disinfection procedure: Usually performed by washing and steaming all surfaces and tools connected with rearing followed by disinfectant spraying -- stages set out below.

	Rearing room	Tools, equipment and outside of rearing room
8th day before hatching	Cleaning	Sort tools and equipment
7th day before hatching	Washing	Wash tools; Spray disinfectant of ground outside rearing room
6th day before hatching	1st disinfection	Dry washed tools in sun
5th day before hatching		Dip tools into 2% formalin; Spray tools with chemical; Cover with vinyl; 1st outside disinfection
4th day before hatching	Open windows	Dry tools in sun
3rd day before hatching		2nd disinfection; 2nd outside disinfection
2nd day before hatching		2nd ground disinfection; Open windows
1st day before hatching		Preparation for hatching

(c) Disinfectant prepararions: The most-commonly used disinfectants are formalin and bleaching powder. A 2% solution of formalin is strong enough for disinfection. This can be prepared by mixing one part of 35% formalin with 16 parts water. After washing the equipment and prior to disinfection the rearing room should be closed and care taken to seal holes and cracks in windows and doors to prevent escape of formalin vapour. Tools should be dried in the sun after disinfection.

4.7.3 Control Measures after Hatching: It is also important to keep silkworms free of pathogens during rearing.

(a) Destruction of infected larvae: Infected dead larvae are one of the most dangerous sources of infection and great care must be taken to ensure their complete destruction. Remove the dead larvae and put into container of diluted disinfectant solution (A); then bury them in the ground taking care that they are not exposed (B).

(A) (B)

(b) Other preventive measures:

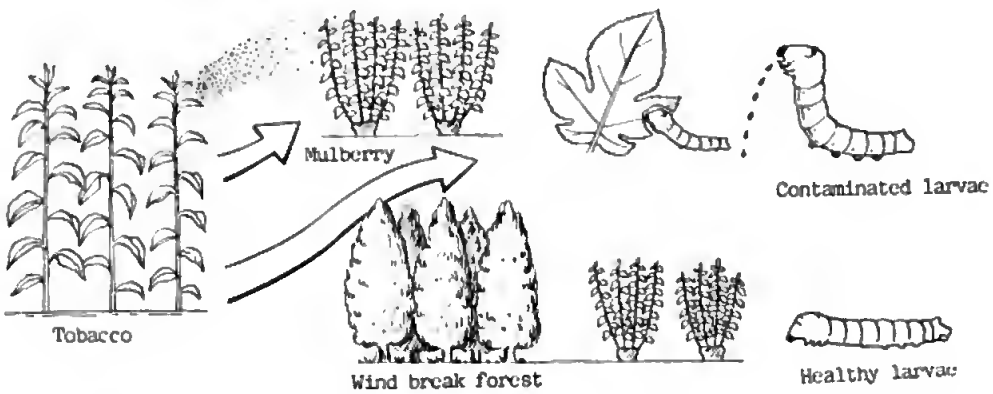
* Maintenance of strict sanitation and hygienic rearing
* Removal and destruction of contaminated materials such as litter by burial underground
* Silkworm body disinfection (A)
* Disinfection of rearing room (B)

4.8 POISONS

Silkworms can be poisoned by eating leaves contaminated by nicotin produced by tobacco plants or by insecticides; larvae are also affected by dust and polluted air from factories and industrial plants. Affected larvae will either die or will not be able to produce cocoons. Farmers must therefore avoid feeding silkworms with contaminated leaves and protect them from pollution.

4.8.1 Tobacco Poisoning

(a) Wind will carry nicotin from tobacco plants on to mulberry trees. Affected silkworms will raise the front part of body and vomit a dark brownish fluid. Lightly affected larvae can recover.



(b) Control measures

* Build mulberry field at least 100m from tobacco field
* Construct wind break against prevailing wind across tobacco field
* Harvest mulberry leaves before tobacco flowers

4.8.2 Pollution

(a) Sources: Electric power stations, fertilizer manufacturers, oil refineries and heavy metal industries produce gases which can poison silkworms.

(b) Symptoms

	Mulberry leaves	Silkworms
Flourine	Edges of leaves become brownish	Loss of eppetite, slow development, vomitting
Cedmium	Tissue of leaf becomes yellowish	Loss of eppetite, slow development, diarrhoea
Zinc	Leef turns dark brown	Loss of appetite, slow development, diarrhoee
Zinc acid	Numerous small dark spots on leaf surfece	As ebove

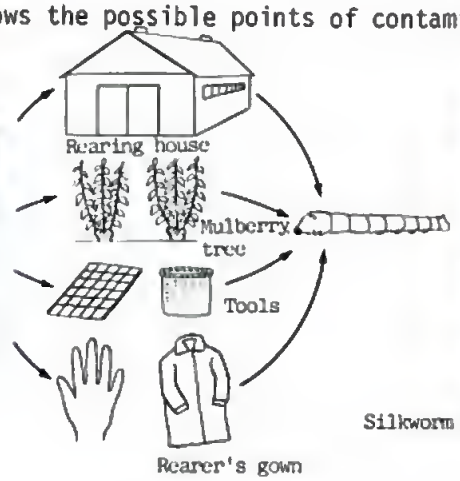
(c) Control measures:

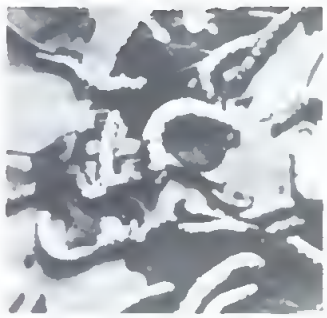
* Prevent factories from being built in sericulture areas
* Ensure that effluent gases strictly controlled

4.8.3 Insecticides

(a) Insecticide contamination: Silkworms are very sensitive to chemical insecticides and the damage caused in this way is increasing year by year. When establishing mulberry fields attention must be paid to the use of surrounding fields. The following diagram shows the possible points of contamination.

Insecticide spray





Silkworm larvae poisoned by insecticide

(b) Symptoms caused by major insecticides

	Insecticide	Symptoms
Organic phosphates	Dipterex DDVP Cidial Sumithion	Silkworms stop feeding Trembling Vomitting
Natural insecticides	Pyrethrin	As above; body becomes S or U form
Sulphur	Lim sulfur Dithan stenless	Larvae slowly lose appetite Sluggishness

(c) Control measures

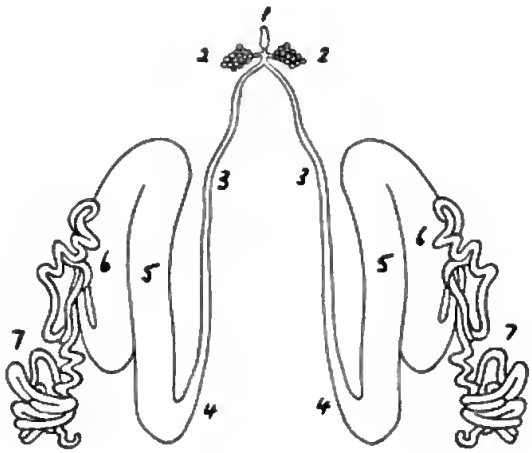
* Test leaf feeds if possibility of contamination
* Replace contaminated shoots with fresh feed
* Ensure rearing sheds are properly ventilated

Chapter 5: REELING OF COCOON

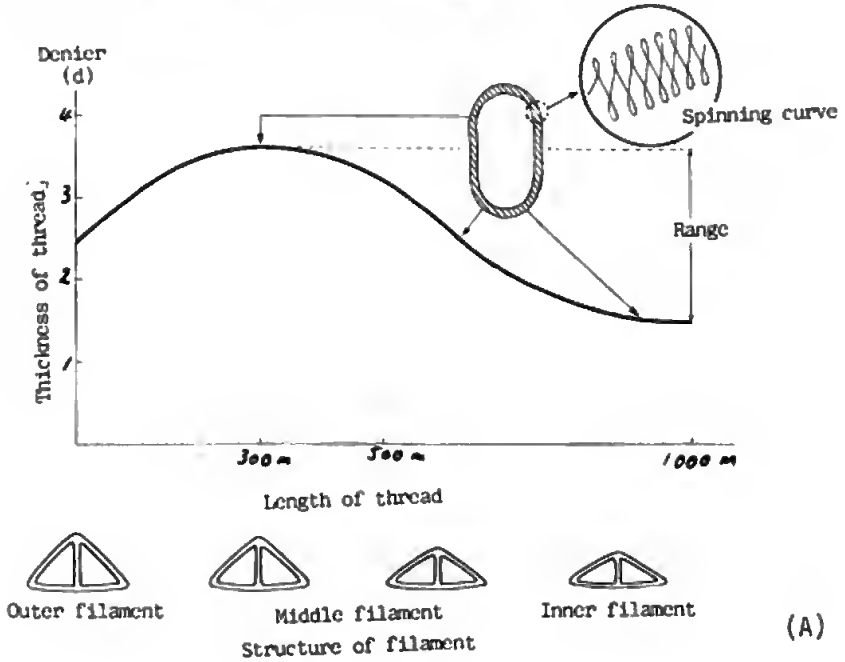
5.1 Structure of silk filament:

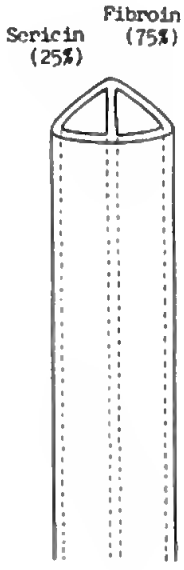
5.1.1 Silk-gland: The cocoon made by the silkworm has a long filament composed of fibroin or real silk and sericin or gum stuff. The following diagram shows the structure of the silk-gland.

1. Spinneret
2. Filippi's gland
3. Anterior division
4, 5, 6. Middle division
   (secretory organ of sericin)
7. Posterior division
   (secretory organ of fibroin)



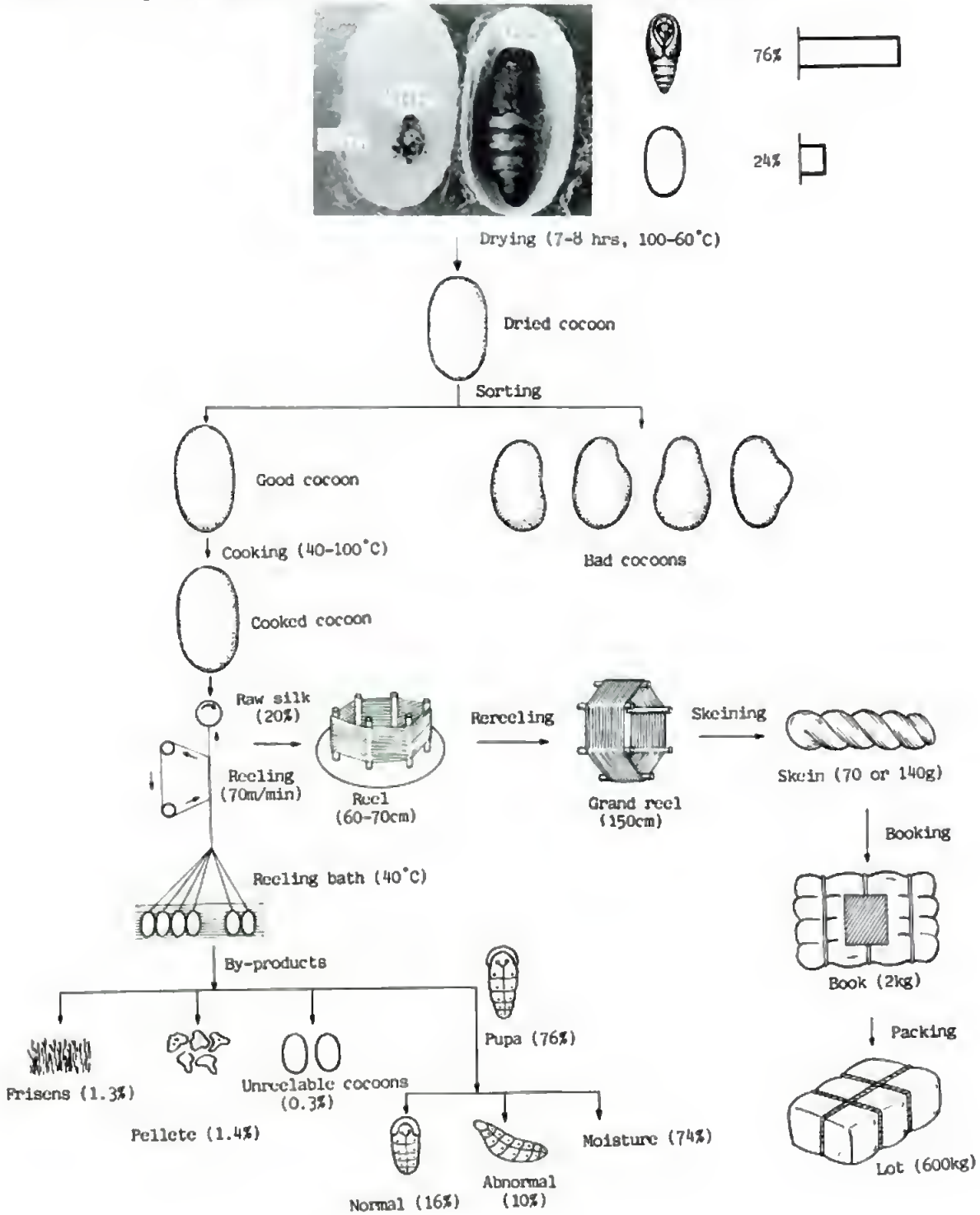
5.1.2 Denier Curve of Cocoon Bave: The following graph shows the variation in thickness of the silk-gland thread (A). The diagram gives a cross-section of the silkworm filament showing its composition (B).





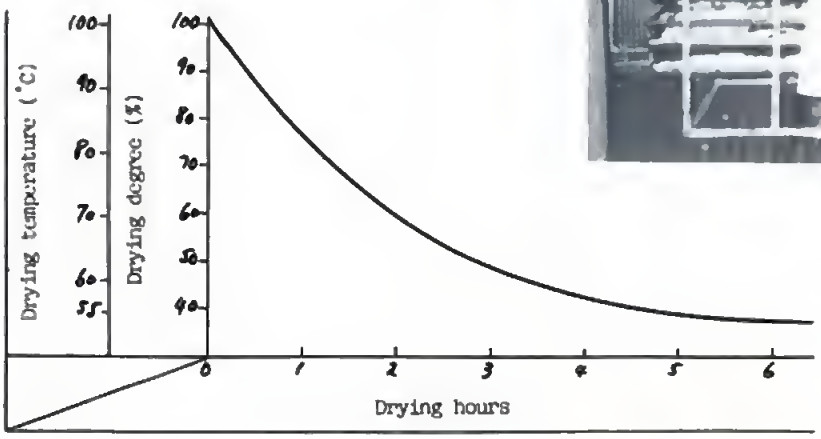
5.2 PROCESS OF SILK REELING

5.2.1 Reeling Process: The following diagram shows the processes involved in silk reeling from the cocoon to final product ready for marketing.

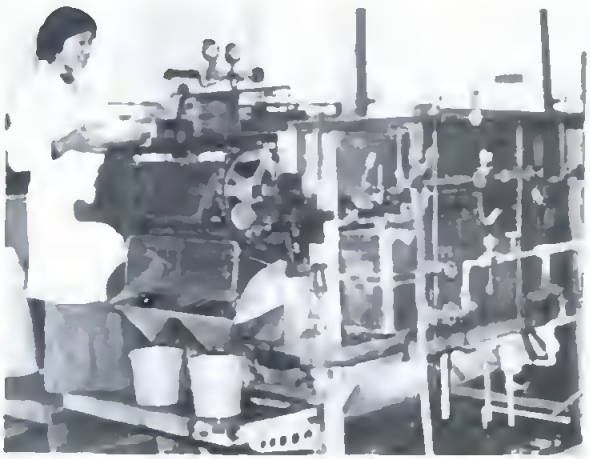


5.2.2 The Process: Fresh cocoons contain live pupae which, in the natural cycle, will moth, breaking the cocoon and making it useless for silk production. To control the cycle the pupae must be killed and the cocoons treated so that they can be stored and used in the reeling process as required.

(a) Cocoon drying: The purpose of this first stage is to kill the pupae and reduce the potentially harmful moisture content, enabling them to be stored up to a year in proper conditions. The graph shows temperature control.



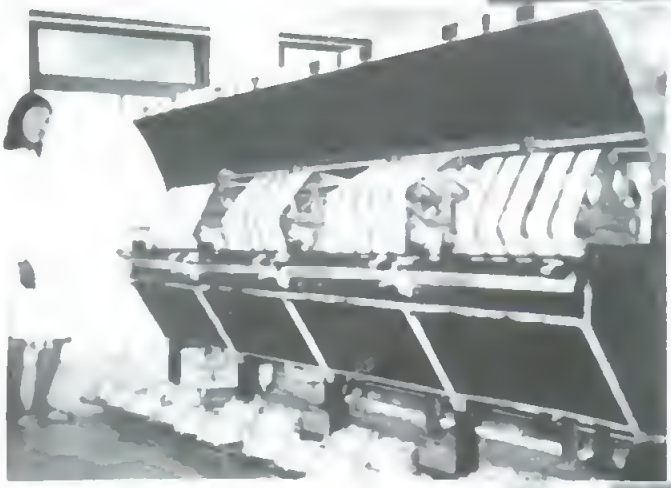
(b) Cocoon cooking: The cocoons are then cooked to separate the gum (sericin) from the fibroin (i.e. de-gumming). The extent of the process determines the quality of the filament produced. Also important in re-establishing water content of cocoon to facilitate reeling. Stages set out in diagram.



Soaking 30-45°C, 1-2min ------> High temp. treatment 80-90°C, 1-2min. ------> Low temp. treatment 30-50°C, 1-2min. ------>

Steam cooking 98-100°C, 2-3min. ------> Cooking control 85-98°C, 3-5min. ------> Finishing 40-65°C, 1-2min

(c) Cocoon reeling: The end of the filament is found by brushing the several ends are joined and reeled on to a spindle making a piece of raw silk thread.



(d) Silk reeling: A standardizing process to produce skeins to international specifications for marketing.

Real circumference: 1.5m

Winding velocity: 150-170rpm

Temperature/humidity: 27-30°C

45-60%RH

Skein weight: 70 or 140g

(e) Silk booking: A number of skeins are joined to form a book which is the standard international sales unit for silk.

(f) Testing of conditioned weight: The book is then weighed at 140°C giving a standard weight.

5.3 SILK WEAVING

5.3.1 Weaving Process: The silk weaving process differs according to kind of silk, kind of fabric to be woven, finishing method and scale of weaving plant. Such staple fibres as spun silk, noil silk and hand-spun silk, until they are woven, are subject to different processes compared with filament fibre such as raw silk, dupion silk and tussah silk. Two processes for spun silk fabric are set out below.

(a) Cheese yarn

warp ---> warping ---> sizing ---> drawing in ---->

weft ---> pirning ----------> weaving ---> dyeing ---> finishing

(b) Skein yarn

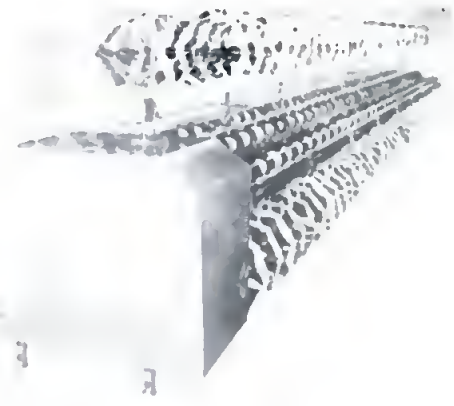
warp (dyed) sizing --> winding --> warping --> drawing in -->

weft (dyed) sizing --> winding --> pirning ----------> weaving --> dyeing --> finishing

5.3.2 Warp Preparation: Includes processes ranging from hanging the raw silk on to weaving machine to weaving a fabric (i.e. winding, sizing, warping, etc.).

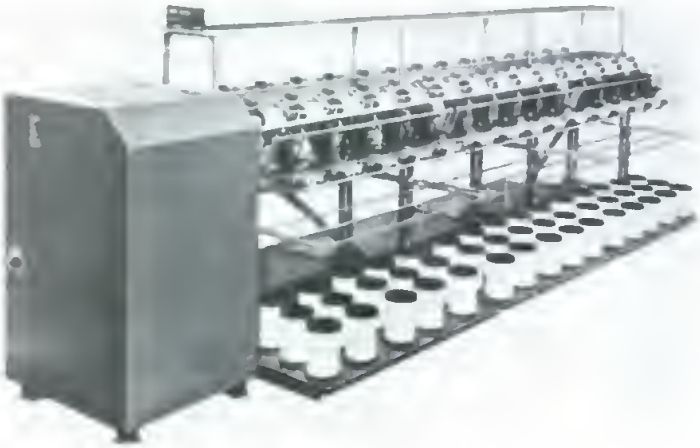
(a) Winding: A preparatory process just before warping when thread is wound around a bobbin (A) on a winder (B).

(A)

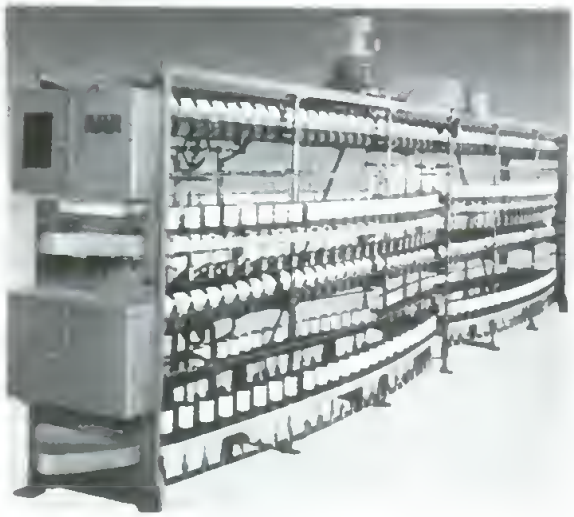


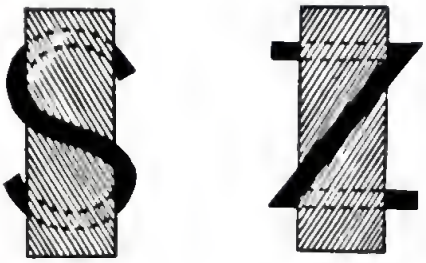
(B)

(b) Doubling: The process in which two or more threads are wound on to one bobbin ready for twisting.



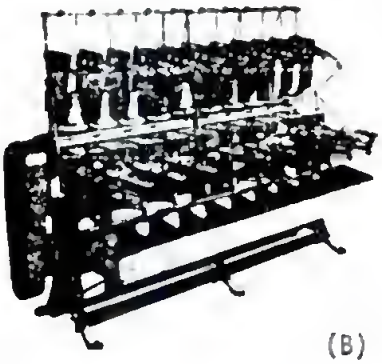
(c) Twisting:



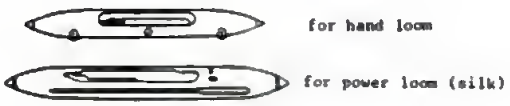


(d) Warping: Threads are wound around the warp beams in preparation for wefting.

5.3.3 Weft Preparation (Pirning): Silk thread is wound on to a pirn which is then inserted in the shuttle (A) ready for the wefting process. The pirning machine is shown below (B).

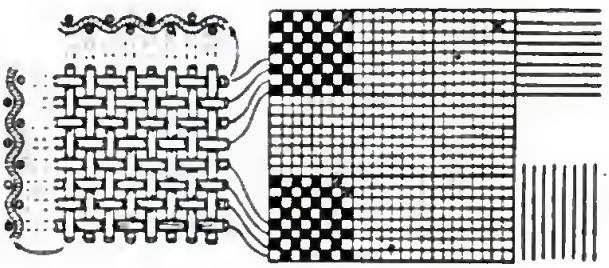


(B)

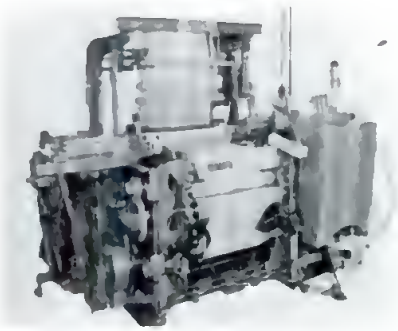


(A)

5.3.4 Weaving: Silk fabric is produced by interlacing the warps arranged parallel to the loom with the wefts running at right angles to them (A). The loom is shown in illustration B.



(A)



(B)

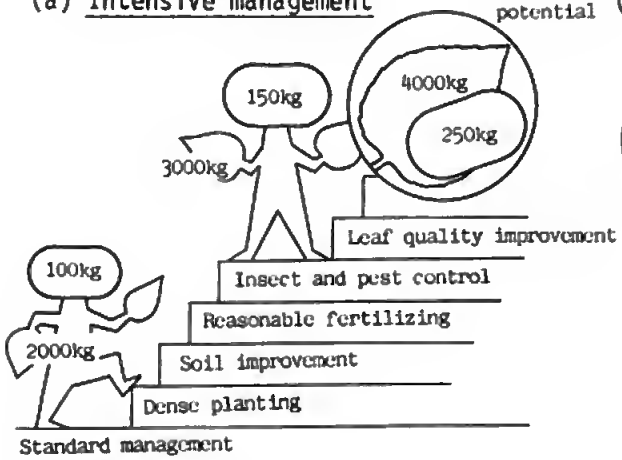
Chapter 6: MANAGEMENT OF SILKWORM REARING

6.1 EFFECTIVE MANAGEMENT OF SILKWORM REARING

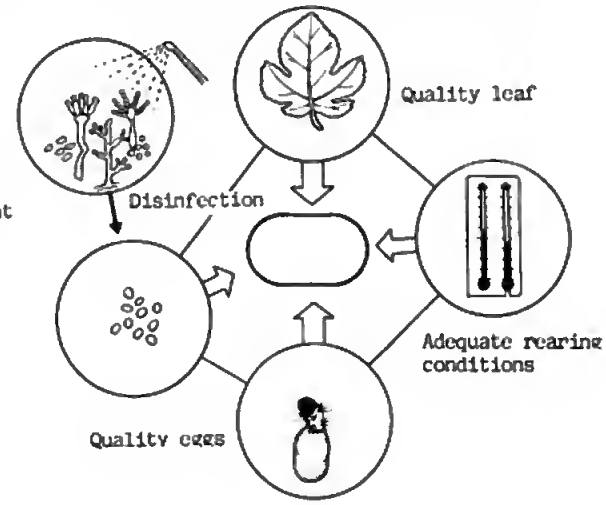
The following sections deal with two areas of silkworm rearing where profitability may be increased -- productivity and operating costs.

6.1.1 Increased Field Productivity

(a) Intensive management

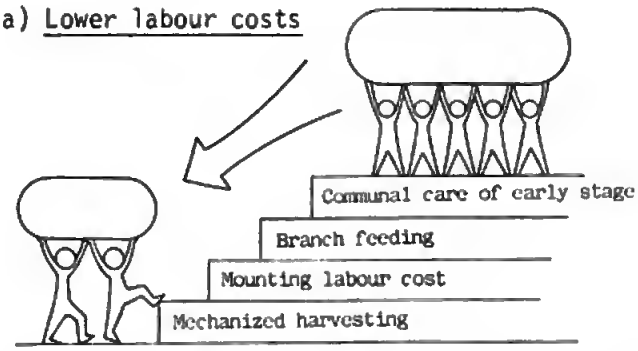


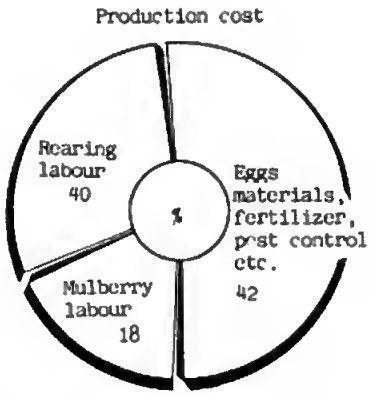
(b) Stabilization of cocoon production



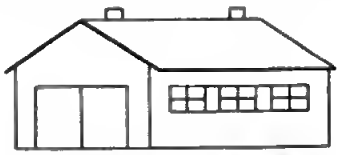
6.1.2 Lower Operating Costs

(a) Lower labour costs



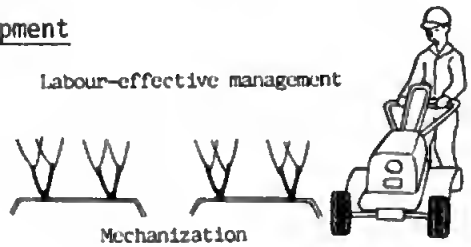


(b) Effective utilization of buildings and equipment



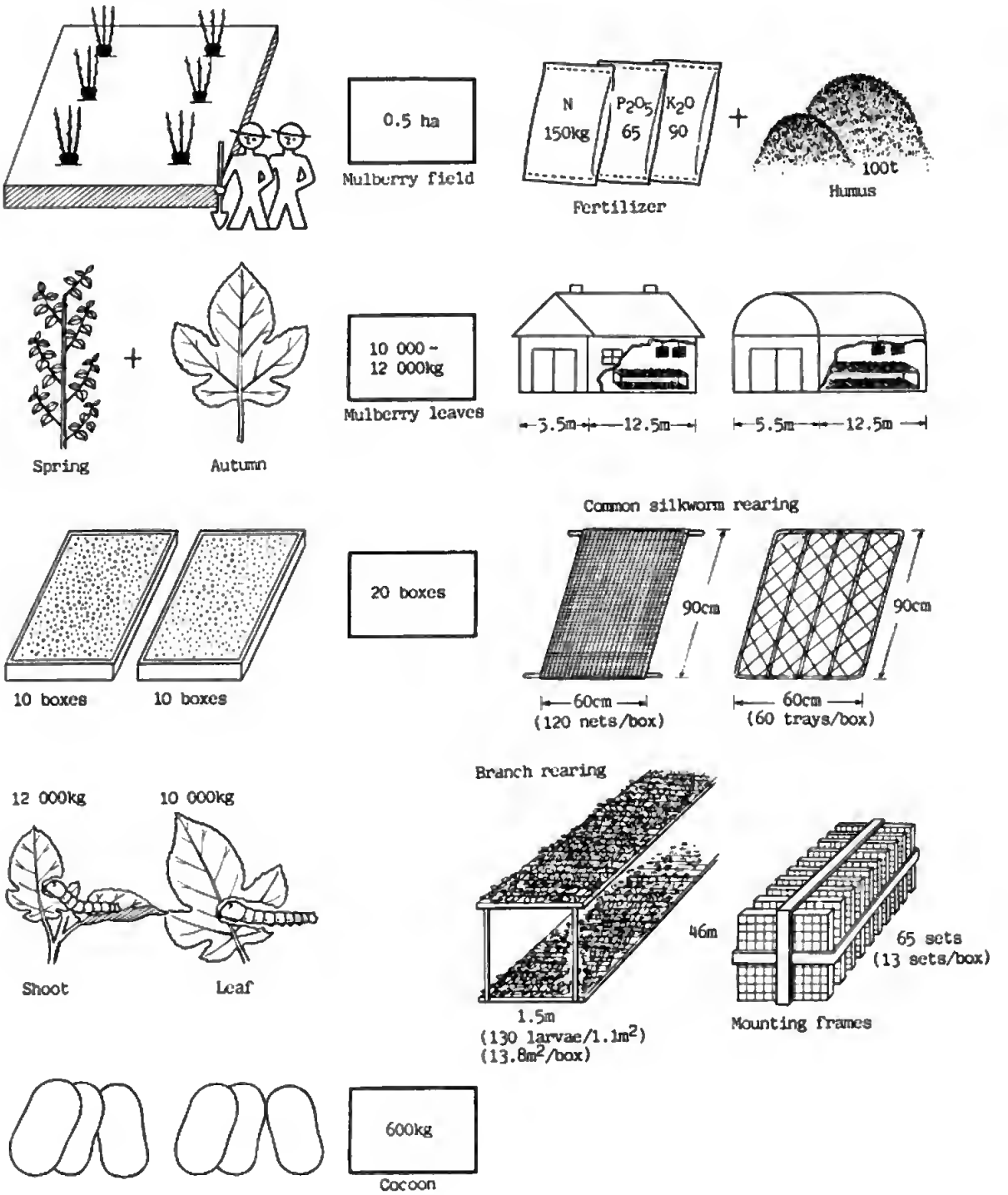
Rearing house and implements (2-4 times/year)

Effective application of chemicals



6.2 MANAGEMENT OF 0.5ha FIELD UNIT

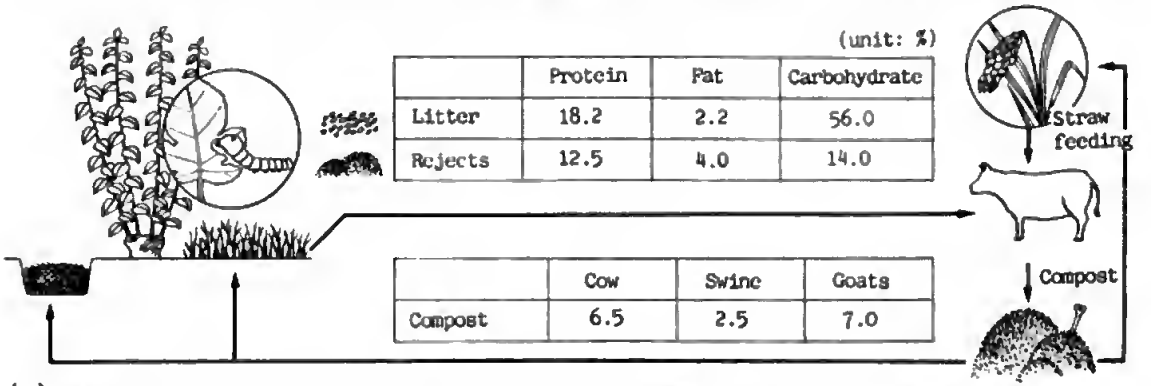
The following diagram shows property and equipment requirements for mulberry field cultivation and silkworm rearing together with harvest expectations for a 0.5ha field unit under standard management.



6.3 COMPLEMENTARY FARMING (temperate zone)

Silkworm rearing can effectively be integrated with other types of farming so as to use labour and other resources to the fullest extent. In addition, by-products of silk production can be used in other farming activities.

(a) Utilization of by-products in complementary farming (silkworm + rice + stock)

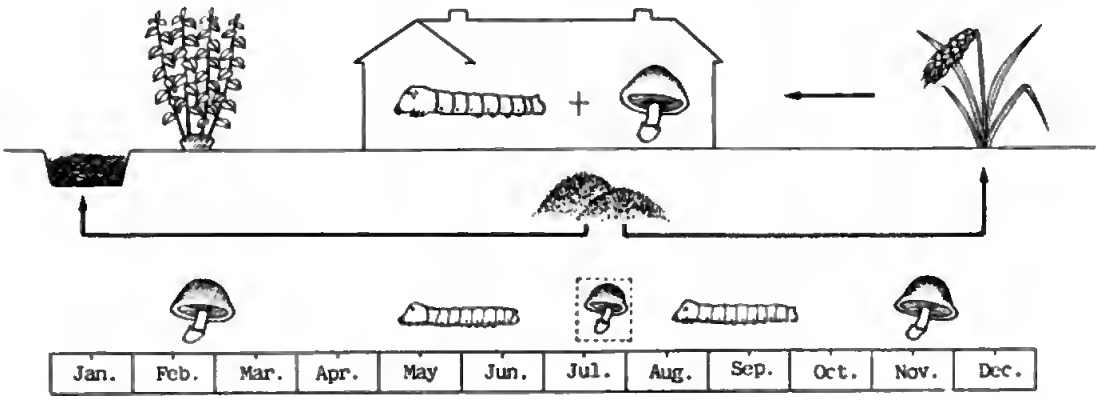


(unit: %)

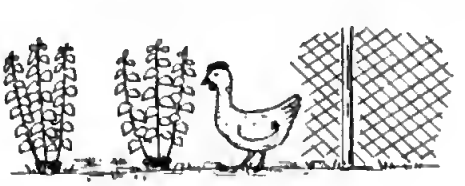
	Protein	Fat	Carbohydrate
Litter	18.2	2.2	56.0
Rejects	12.5	4.0	14.0

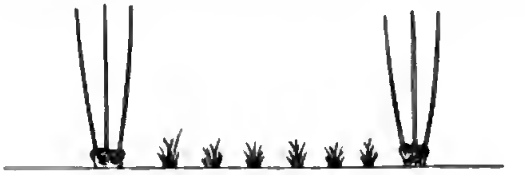
	Cow	Swine	Goats
Compost	6.5	2.5	7.0

(b) Year-round utilization of rearing house: The following diagrams show how mushroom cultivation can conveniently be practised with silkworm rearing making the fullest use of facilities when not being used for rearing of silkworms.



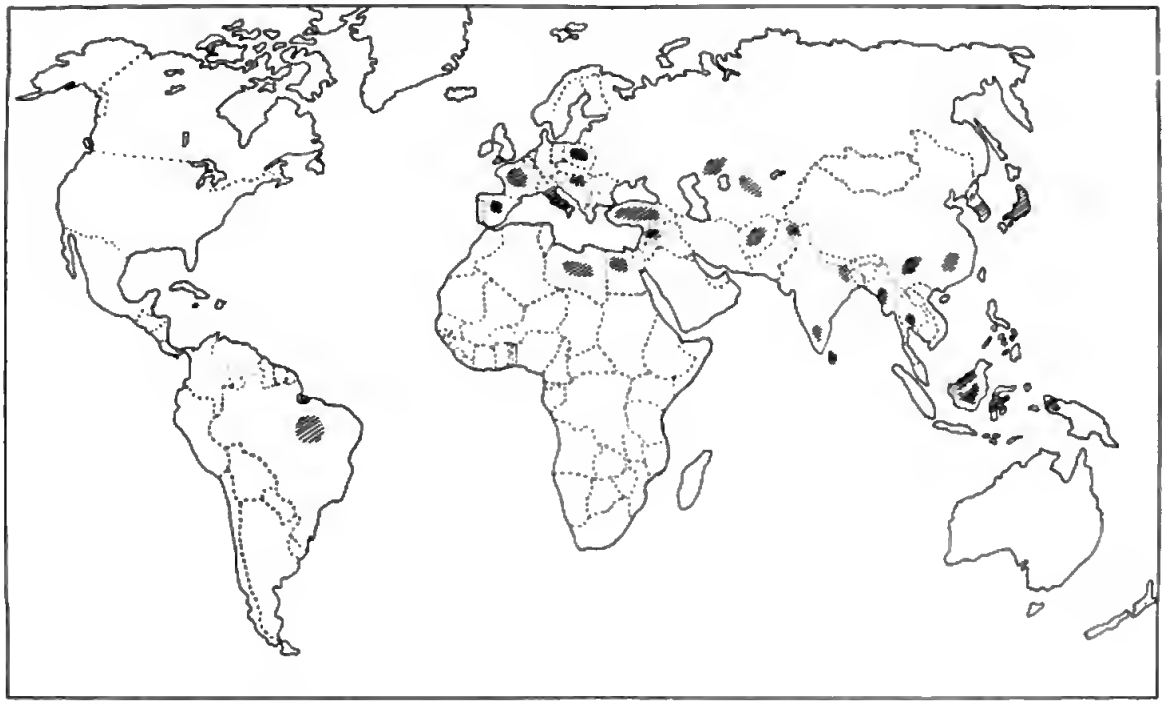
(c) Multi-use of mulberry field: Poultry farming can conveniently and profitably be carried out using the mulberryfield -- as well as being an effective insect/pest control, 200 chickens/ha will provide 10kg of manure/yr. A winter crop between the rows will provide additional income and can be beneficial to the trees.



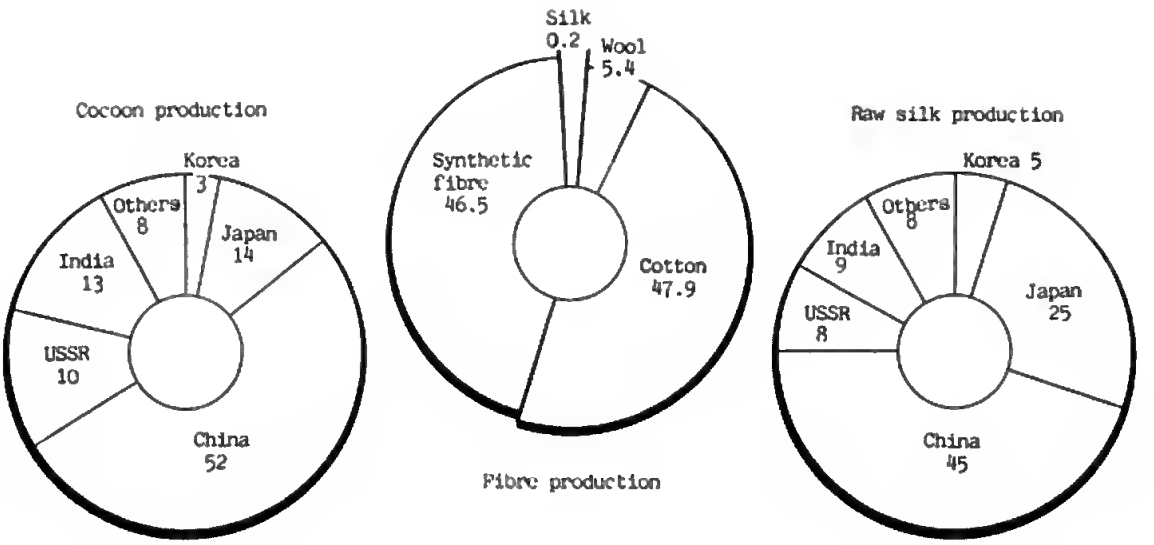


APPENDIX I

(a) World Distribution of Mulberry Trees



(b) World Silk Production



APPENDIX II

Some Facts about Silkworm Cultivation and Production

(a) Mulberry consumption vs. cocoon production

Shoot (spring season): 20kg

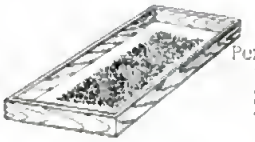
Leaf (autumn season): 18kg

(b) Calculation of sapling density per 0.1ha

$$\text{Sapling number} = \frac{1\,000\text{sq m}}{\text{distance between plants (m)} \times \text{distance between rows (m)}}$$

(c) Fecundity

500-700 eggs/Female



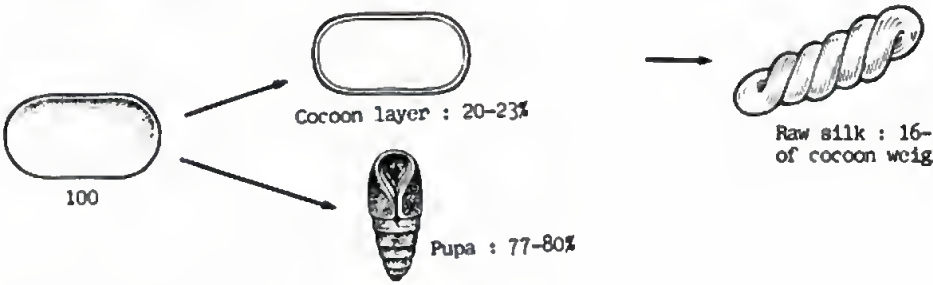
Per box
10.6-12.8g
20 000 eggs
7.4-9.0g of young larvae

(d) Cocoon weight

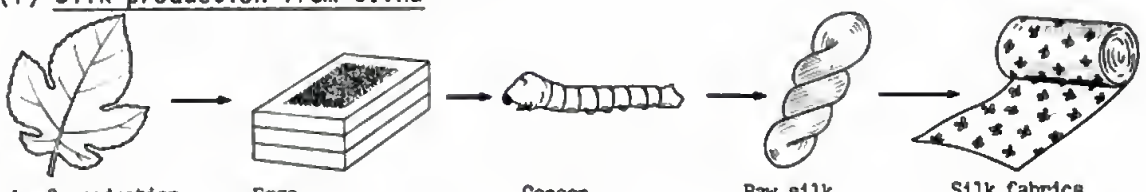
Spring: 2.0-2.3g
Autumn: 1.8-2.0g

Length : 1 200m - 1 300m
Thickness: 2.6-3.2 Denier

(e) Cocoon composition



(f) Silk production from 0.1ha



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